VOL·XIV NO·3

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

S·A·E

MARCH 1924

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XIV March, 1924 No. 3

Chronicle and Comment

Standard to Facilitate Service

THE Standards Committee is formulating a specification intended primarily to facilitate service. It is not always possible for a standard to be developed for accomplishing such a desirable result without requiring an increase in the cost of production. Therefore, it is well worthwhile for everyone connected with the industry to review the proposed method of identifying electrical circuits by a color-code that has been proposed by a Subdivision of the Electrical Equipment Division. It is printed on p. 338 of this issue of THE JOURNAL.

Transportation Mediums

ESSENTIALLY highways transportation need not conflict with other kinds of distribution. It cannot haul the 2,500,000,000 tons of freight carried by the railroads in a normal year, nor transport such part of their 1,000,000,000 passengers as ride long distances. It cannot give service in congested municipal areas to the 16,000,000,000 yearly electric-trolley passengers. But it can serve the public over 2,750,000 miles of highways, the greater portion of them not cared for by any other transportation element.—George M. Graham.

The Transactions

COPIES of Part II of Vol. 17 of the TRANSACTIONS were mailed early last month to the 437 members who had placed orders for them. Such of the papers presented at the 1922 Semi-Annual Meeting and the Detroit Production Meeting of the Society and those presented at Section meetings and printed in the July to December, 1922, issues of THE JOURNAL inclusive as were considered by the Publication Committee to have sufficient engineering value to warrant reprinting are included, together with the discussion following their presentation, in this volume, which consists of 849 pages.

In accordance with the resolution adopted by the Council at its meeting on March 7, 1922, this is the last part of the TRANSACTIONS that will be distributed to the members without charge other than the payment of regular dues. Beginning with Part I of Vol. 18, covering the TRANSACTIONS for the first half of 1923, a charge of $2 per part will be made. The change in the policy of distributing the TRANSACTIONS from that of general distribution has resulted in a marked reduction in the number of copies printed. For example, 4500 copies of Part I of Vol. 15, covering the first half of 1920, were printed, this being the last part that was distributed generally. Of the next part of the TRANSACTIONS, which was the first supplied upon order, only 1800 copies were printed; and 600 copies were sufficient to take care of the orders received for the TRANSACTIONS for the last half of 1922.

Personal Contact Between Designer and Service-Manager

ONE of the most acute discussions and issues prevalent recently relates to the matter of the necessity for and the extent of contact between the engineering departments and the service-stations of motor-vehicle companies. The service-managers have insisted that they have not personal contact with the designers of the vehicles they have the duty of maintaining. Assuming that the engineers should maintain personal contact with them, some service-managers say that the factory service-departments are barriers and that the engineers are not sufficiently conscientious about calling at service-stations even when they are near them on other business.

The engineers have pointed out that in a large organization involving a great variety of duties, it is impossible as well as impracticable for one man to keep in direct contact with the details of engineering, manufacturing and service. These men feel that the position of an engineer in an automobile company is misunderstood by the service-managers of various dealers, and that they would have the engineer take up part of the duties of the service-manager or of some member of the service department. It is the duty of the service department to keep in constant touch with the results the product is giving in performance. It is, of course, important for the engineering department to have information of this kind available, but some engineers believe that a large part of it should come through the factory service-department. In this connection it is stated that usually 90 per cent of the communications from service-managers in the field relates to manufacturing detail, that is, to things that go wrong from day to day in the factory. Most of these matters have no real bearing upon

design and those that do are reiterated to such an extent that the engineering department hears of and remedies them more quickly and economically than if the engineering department were in direct contact with the distributors.

Time Element in Engineer's Work

Many of the car-builders have established their service departments as subsidiaries of their sales departments. It is argued that this is proper in the case of large organizations. The engineers state that they now receive more letters than they can handle adequately and that they have not the time they should have to spend with designers in the drafting-room, with the mechanics in the experimental room or with the engineers in the testing laboratories, because they are burdened with correspondence in general. If they undertook to communicate directly with their hundreds, and even thousands, of service-managers, they would not have any time left to do engineering work. These engineers keep in close touch with the service-men through the home office and in some cases by sending experts into the field periodically. One engineer remarked that the designers are in closer contact with the troubles of service-men than the latter realize. The further opinion is advanced that the placing of the service department under the jurisdiction of the engineering department would impair the efficiency of the latter.

Engineers appreciate that much valuable information is available from the service-managers as to the actual operating conditions in the field, provided the complaints of the service-managers are based upon good analysis and are not overdrawn. If all of the suggestions that were submitted by the service-managers and service departments were embodied in the product of a company, continual changing of design would result. In one factory the communications received from service-men are tabulated monthly to show the number of similar complaints per car per year, emphasizing the frequency or rarity of the various complaints.

Gap Between Design and Service

On the other hand, it is contended that the gap between the actual field-service and the designing and engineering divisions is a fundamental weakness of the automobile industry. The point is constantly made, however, that much of the information received from the field is misleading and that in diagnosing at the home office the engineer has to discount prejudice and pet theories of men in the field. In one instance, where difficulties arise which cannot be properly interpreted by the factory service-department, direct communication is had between the engineering and the field organizations. Also, in case of long-time guarantee of a car, the policy is to make the service department effective in preventing rather than curing troubles.

One motor-vehicle builder at least is so organized that service is included in the duties of the engineering department, the service department being a part of the engineering branch. The service-managers of its branches are selected by the engineering department. All information pertaining to service is given by the engineering department. If a company has not a separate service-department, information as to maintenance troubles would probably have to be collected by the engineering department.

Importance of Service

Undoubtedly the longer a company has been in business, the more it appreciates the advantage of having all necessary service work done promptly and efficiently. Some engineers acknowledge freely that at the present time there is not a proper amount of cooperation between engineering departments and service-stations in general. It is also said that it is much easier for the service branch to secure complete definite information from the engineering department than for the engineering department to elicit useful information from the field. Anything that can be done to foster closer cooperation between engineering and service is decidedly worthwhile. The engineers are not unappreciative of the necessities and problems involved. One engineering department maintains a loose-leaf information manual that is circulated to all its dealers and sub-dealers. This procedure is based upon the conviction that very close contact should be maintained with the dealers.

The information developed in the field in the maintaining of automobiles is not belittled by the engineers. Some of the most important data relative to car performance have come through this source. Engineers have relatively little time to devote to the promotion of contact with the men in the field but do in general endeavor to supply promptly and clearly any information requested. Most engineers feel that the service-men usually have sound reasons for their complaints and that the best way in which to improve the product is to know the conditions in the field.

Personal Relations

Most of the chief engineers of the leading companies know more or less well the service-managers of their companies and visit their service-stations when they have an opportunity to do so. Some of them maintain correspondence regularly with the field men, the degree of this being usually in an inverse ratio to the number of cars produced so far as the whole Country is concerned. It is the problem of the car-owner that the engineer is interested in fundamentally. It is his ambition to eliminate so far as possible the necessity of service-station attention to his product.

One large company has a number of service-managers in its sales department, all of these being under the direction of a national service-manager. The last-named sends all complaints to the manufacturing service-manager and the latter takes up with the production department complaints relating to production and with the engineering department complaints connected with engineering. It is the duty of the chief engineer to send out all necessary information through the manufacturing service-manager who has men working in the field and himself visits the service-managers in the larger cities periodically. In the case of another company the distributors have in their service departments men who have had training at the factory. The company has also traveling service-men whose duty it is to maintain contact with the service-managers of the various distributors, among other things giving information as to how work can be done most economically and adjustments properly made. All problems that require change in design or material are brought to the attention of the engineering department by the service department. Annual meetings of the service-men are held. Friendly relations with service-men can be maintained best by analyzing their complaints and making changes that are justifiable in connection with them. Many troubles are due to improper handling of the mechanism, to neglect

(*Concluded on p. 306*)

Economic Motor-Fuel Volatility

By Roger Birdsell[1]

Annual Meeting Paper *Illustrated with* Charts and Photograph

REPORTING on the progress of the fuel investigation now being conducted by the Bureau of Standards, and covering the last of the work that was done under the direct supervision of the late Stephen M. Lee, the author gives the results obtained from the acceleration tests that were made on the road and in the laboratory. Tests relative to starting conditions, as called for by the program, have yet to be made; they have been delayed by the wreckage of the laboratory set-up caused by the explosion of Sept. 20, 1923.

Primarily, the tests described here were conducted (*a*) to determine whether the rates of acceleration obtainable at any given temperature are different for the fuels compared, and (*b*) whether, when carbureter settings are such as to give the maximum acceleration with each fuel, the fuel consumption under constant speed and load conditions will be greater with one fuel than with the other. Two specific conclusions are stated.

W. S. James, physicist, Bureau of Standards, gives an analytical description of the design of the disc used to simulate the inertia of a car and treats this mathematically in Appendix 1.

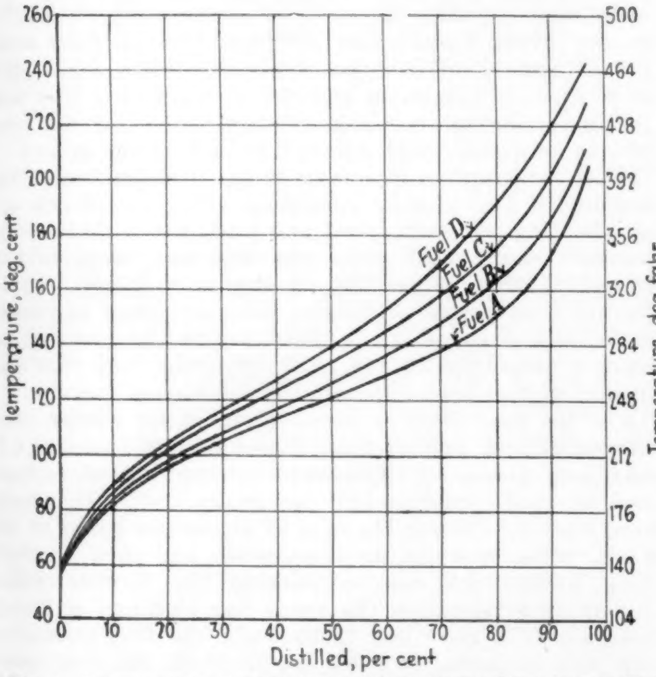

Fig. 1—Distillation Curves of the Four Fuels Used in the Tests
The Volatility of These Fuels Varies, *A* Having the Highest and *D* the Lowest. The *B* Fuel Corresponds Rather Closely to the Average 1922 Commercial Fuel

THIS paper is a progress report of the fuel investigation now being conducted by the Bureau of Standards in cooperation with the American Petroleum Institute, the National Automobile Chamber of Commerce and the Society of Automotive Engineers. It discusses results obtained since June, 1923, when a progress report was presented to the Society at its Semi-Annual Meeting.

TABLE 1—PHYSICAL CHARACTERISTICS OF THE FOUR TEST-FUELS

	Fuel							
	A		*B*		*C*		*D*	
	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.
Distillation, Initial	49.0	120	52.0	126	51.5	125	54.5	130
10 Per Cent	83.0	181	83.5	182	84.5	185	89.0	192
20 Per Cent	94.0	201	96.3	205	102.0	216	104.5	221
30 Per Cent	105.0	221	106.7	225	113.5	237	116.0	241
40 Per Cent	113.5	237	116.3	241	124.5	257	128.0	262
50 Per Cent	121.0	250	126.2	259	134.0	275	139.0	282
60 Per Cent	130.0	266	136.0	277	145.0	293	153.0	307
70 Per Cent	139.5	284	148.0	298	159.0	318	170.5	338
80 Per Cent	149.5	302	163.7	327	176.5	351	194.0	381
85 Per Cent	158.0	316	172.0	342	186.0	367	204.0	399
90 Per Cent	171.5	342	185.0	365	201.0	394	218.5	426
95 Per Cent	192.0	378	203.0	397	218.0	424	233.0	452
End, or High Point	206.5	403	214.0	417	229.5	446	244.5	472
Average Boiling-Point	121	250	125	257	135	275	142	288
Equilibrium Temperature[2]	151	304	163	325	176	349	192	378
Dew-Point, 12 to 1 Mixture[2]	11	52	31	88	47	117	67	153
Average Molecular Weight[2]	111.5		114.0		119.5		123.5	
Specific Gravity at 26 Deg. Cent. (78.5 Deg. Fahr)	0.727		0.733		0.736		0.740	
Index of Refinement, (26 deg. Cent.=78.5 Deg. Fahr.)	1.4110		1.4110		1.4150		1.4165	
Viscosity at 26 Deg. Cent. (78.5 Deg. Fahr.), centipoises	0.527		0.533		0.577		0.592	
Doctor Test	Sweet		Sweet		Sweet		Sweet	
Unsaturated Compounds, per cent	5.5		6.5		6.0		6.0	
Moisture Content	None		None		None		None	
Acidity	None		None		None		None	
Reaction Test	None		None		None		None	

[2]Wilson's Method.

The primary object of this investigation has been to obtain adequate data for estimating satisfactorily the effect of certain changes in fuel volatility upon the performance of automobiles now in service. For this purpose four fuels designated by the letters *A*, *B*, *C* and *D* were selected. The characteristics of and reasons for selecting these fuels have been covered in previous reports but, for reference purposes, the characteristics are

TABLE 2—ESTIMATED PRODUCTION OF FOUR TEST-FUELS, COMPARED WITH GRADE-*B* FUEL

Refiner	Fuel *A*	Fuel *B*	Fuel *C*	Fuel *D*
1	81	100	114	128
2	91	100	111	124
3	83	100	113	122
4	84	100	115	133
5	90	100	112	145
Average	86	100	113	130

[1]S.M.S.A.E., associate mechanical engineer, Bureau of Standards, City of Washington.

shown again. Fig. 1 shows distillation curves; Table 1, physical characteristics; and Table 2, a comparison of the estimated production of the four fuels. The program that was outlined and is being followed in this investigation is as follows:

(1) Fuel-Consumption Tests—Summer Conditions—on Road
(2) Crankcase-Oil Dilution—Summer Conditions—on Road
(3) Fuel-Consumption Tests—Winter Conditions—on Road
(4) Fuel-Consumption Tests—Winter and Summer Conditions—Constant Speed and Load—Laboratory Set-Up
(5) Crankcase-Oil Dilution—Winter and Summer Conditions—Constant Speed and Load—Laboratory Set-Up
(6) Accelerations—Winter Conditions—on Road
(7) Accelerations—Winter and Summer Conditions—Laboratory Set-Up
(8) Starting

The purpose of this program was to obtain data that would be instrumental in answering the paramount question of whether the overall cost of transportation would be reduced by the use of a fuel such as *D*, instead of one of a higher volatility such as *B*. It was believed by some that, in ordinary service, even in warm weather, the use of *D* fuel instead of *B* would cause a greater percentage increase in the fuel consumption per mile than the estimated percentage increase in the fuel production per barrel of crude oil. Were such the case, the production of *D* fuel for use in automobiles then in service, in 1922, would have been unwise, as it was admitted generally that *D* fuel was inferior to *B* to some extent, as regards the rate of crankcase-oil dilution and ease of starting. The results of items (1) and (2) in the foregoing program were given in a report made by R. E. Carlson to the Society.[2] Items (3), (4) and (5) were covered in a similar report made by the late Stephen M. Lee to the Society.[3] This paper will cover items (6) and (7); that is, accelerations, both on the road and in the laboratory. Item (8) is not completed, having been delayed because of the recent explosion that wrecked the laboratory set-up.

[2] See THE JOURNAL, February, 1923, p. 139.
[3] See THE JOURNAL, July, 1923, p. 3.
[4] See THE JOURNAL, February, 1923, p. 143.

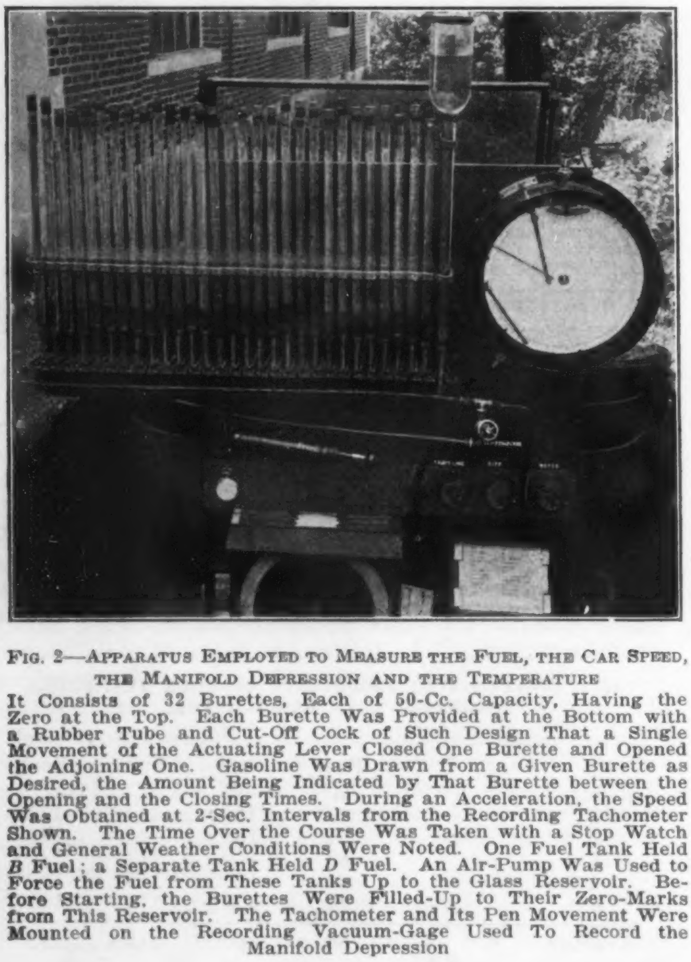

FIG. 2—APPARATUS EMPLOYED TO MEASURE THE FUEL, THE CAR SPEED, THE MANIFOLD DEPRESSION AND THE TEMPERATURE

It Consists of 32 Burettes, Each of 50-Cc. Capacity, Having the Zero at the Top. Each Burette Was Provided at the Bottom with a Rubber Tube and Cut-Off Cock of Such Design That a Single Movement of the Actuating Lever Closed One Burette and Opened the Adjoining One. Gasoline Was Drawn from a Given Burette as Desired, the Amount Being Indicated by That Burette between the Opening and the Closing Times. During an Acceleration, the Speed Was Obtained at 2-Sec. Intervals from the Recording Tachometer Shown. The Time Over the Course Was Taken with a Stop Watch and General Weather Conditions Were Noted. One Fuel Tank Held *B* Fuel; a Separate Tank Held *D* Fuel. An Air-Pump Was Used to Force the Fuel from These Tanks Up to the Glass Reservoir. Before Starting, the Burettes Were Filled-Up to Their Zero-Marks from This Reservoir. The Tachometer and Its Pen Movement Were Mounted on the Recording Vacuum-Gage Used To Record the Manifold Depression

ACCELERATIONS

From preliminary tests it did not appear that the difference between the performances, during acceleration, of fuels *A*, *B*, *C* and *D* was very marked. Further efforts therefore were concentrated on fuels *B* and *D*. The *B* fuel corresponded rather closely with the average commercial fuel of 1922; the *D* fuel had the lowest volatility of any of those under consideration.

The purpose of the tests was primarily to answer the questions, (*a*) Are the rates of acceleration obtainable at any given temperature different for the fuels compared? and (*b*) When the carbureter settings are such as to give the maximum acceleration with each fuel, will the fuel consumption under constant speed and load conditions be greater with one fuel than with the other?

Fuel consumption in service is apt to depend upon the amount of fuel that is consumed under conditions approximating constant speed and load, but with the carbureter setting that gives the maximum acceleration. It is true that, in service, an engine does not operate for any long period of time at constant speed and load, but sudden changes in the speed and the load occupy so small a proportion of the total operating time that the amount of fuel used is practically unchanged thereby.

For the road tests of acceleration under winter conditions, cars *W* and *Z*, fuels *B* and *D*, and a course 0.3 miles long were used. The course selected was an asphalt road, in good condition and practically level. The tests were made by driving the cars at a constant speed of 10 m.p.h. while approaching the course, and then accelerating for the 0.3 mile by opening the throttle wide. During an acceleration the speed was obtained at 2-sec. intervals by a recording tachometer, the fuel consumption was measured in cubic centimeters, the time over the course was taken with a stop-watch and general weather conditions were noted. Fig. 2 shows the recording tachometer and gasoline-measuring system used in these tests, mounted on one of the cars. This apparatus has been described in a previous report to the Society.[4]

The results obtained are shown in Table 3 and in Figs. 3 and 4. Table 3 shows the time required for the accelerations and the fuel consumption. Fig. 3 shows car speeds plotted against time for car *W* over a range of carbureter settings, and Fig. 4 shows the time necessary to accelerate from 12 to 30 m.p.h. over a range of carbureter settings for the same car. From Fig. 3 it will be noted that the car speeds, from which accelerations were made, vary slightly due to the inability of the operator to maintain a car speed of exactly 10 m.p.h.

The conclusion reached was that the difference in acceleration as between the two fuels was not measurable by road tests, at least for air temperatures of 5 deg. cent. (41 deg. fahr.) and up. It was realized, however,

that the inability to show any difference in acceleration between the two fuels might, to some extent, be due to the fact that a close control of air and water temperatures was impossible. This in part prompted the decision to make further acceleration tests in the laboratory.

For the laboratory tests, the *Z* engine was used. On the end of the dynamometer armature-shaft, a steel disc was mounted of such dimensions that when its inertia was added to that of the armature, the sum equalled the inertia of the *Z* car.

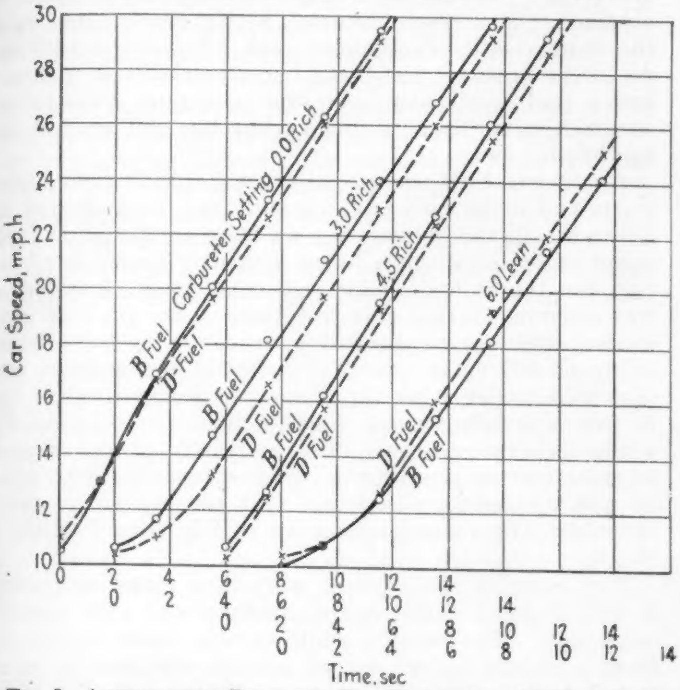

FIG. 3—ACCELERATION RUNS FOR CAR *W* OVER THE 0.3-MILE COURSE
These Runs Were Made at Air Temperatures Ranging from 1 to 9 Deg. Cent. (33.8 to 48.2 Deg. Fahr.) and Water Temperatures of from 35 to 45 Deg. Cent. (95 to 113 Deg. Fahr.) with Various Carbureter Settings for the *B* and *D* Fuels. It Will Be Noticed That the Car Speeds, from Which the Accelerations Were Made, Vary Slightly Due to the Inability of the Operator To Maintain a Car Speed of Exactly 10 M.P.H.

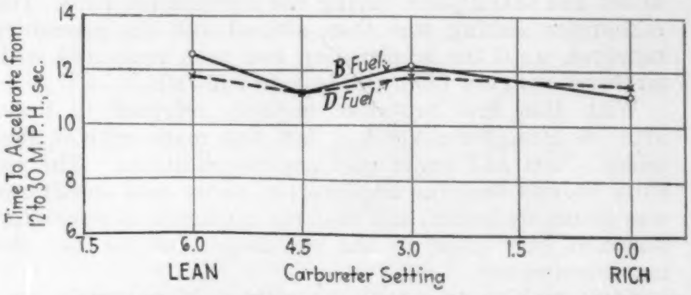

FIG. 4—TIME REQUIRED TO ACCELERATE CAR *W* FROM 12 TO 30 M.P.H.
These Results Were Obtained under the Same Air and Water Temperatures as Those Plotted in Fig. 3. The Very Slight Difference in the Acceleration with the Two Fuels Shown by the Road-Tests Was Partly Responsible for the Decision To Make Further Acceleration Tests in the Laboratory

Test Procedure

The procedure first used in making the tests was as follows: The desired air and water temperatures were first obtained, and then a power and fuel-consumption run was made at 600 r.p.m., at full throttle. This run served to identify the carbureter setting and was also a check on the engine condition. The next step was to adjust the electrical load to a torque of 33 lb-ft. while maintaining a speed of 600 r.p.m. The engine was then accelerated by opening the throttle wide. Measurements of acceleration were obtained by recording successive readings, at 2-sec. intervals, of a chronometric tachometer until the maximum speed had been reached. A number of such runs were made, and the results were averaged. Another measurement of power and fuel consumption was then made at 600 r.p.m. at full throttle, to make sure that no change in the engine con-

TABLE 3—ACCELERATION TESTS ON LEVEL ASPHALT ROAD FROM 10 M.P.H. UPWARD OVER 0.3-MILE COURSE[5]

Mixture, Lean to Rich	Carbureter Settling	Date	Total Time, Sec.		Fuel Consumption					
					Total Fuel Used, CC		CC per Sec.		Miles per Gal.	
Fuel			*B*	*D*	*B*	*D*	*B*	*D*	*B*	*D*
Car *W*										
	6.0	Jan. 29	34.6	35.9	108.8	110.4	3.15	3.07	10.4	10.3
Lean	6.0	Jan. 30	35.0	35.0	113.0	110.2	3.33	3.15	10.1	10.3
	4.5	Jan. 30	33.2	34.2	124.4	123.6	3.75	3.61	9.1	9.2
Garage Setting	3.0	Jan. 29	33.0	34.4	139.3	133.6	4.22	3.89	8.2	8.5
	3.0	Jan. 30	34.0	33.6	137.0	132.6	4.03	3.95	8.3	8.6
Rich	0.0	Jan. 30	32.2	32.6	156.2	157.8	4.85	4.84	7.3	7.2
	9.0	Jan. 29	33.6	33.4	153.4	155.4	4.57	4.65	7.4	7.3
Car *Z*										
	4.6	Jan. 29	35.8	37.0	68.0	65.1	1.90	1.76	16.7	17.5
Lean	4.0	Jan. 20	37.0	35.5	76.0	70.9	2.05	2.00	15.0	16.0
	2.6	Jan. 26	38.4	36.8	81.8	79.6	2.13	2.17	13.9	14.3
	2.4	Jan. 30	35.8	34.7	82.8	82.0	2.31	2.36	13.7	13.9
Garage Setting	1.4	Jan. 29	36.5	37.2	117.2	94.0	3.21	2.53	9.7	11.7
Rich	1.0	Jan. 26	36.5	......	129.0	......	3.58	......	8.8	......
	1.0	Jan. 30	35.0	35.0	98.4	104.8	2.81	2.99	11.5	10.8

[5] Air Temperature, 1 to 9 deg. cent. (33.8 to 48.2 deg. fahr.)
Outlet-Water Temperature, 35 to 45 deg. cent. (95 to 111 deg. fahr.)

dition had taken place during the acceleration runs. The carbureter setting was then altered and the procedure repeated, until the acceleration had been measured with mixtures ranging from full-lean to full-rich.

With this first tentative method, referred to hereafter as Procedure No. 1, a test was made with *B* fuel under warm and under cold engine-conditions. The results showed that the acceleration under cold conditions was distinctly better, and that the maximum acceleration occurred very close to the carbureter setting for the maximum power.

After making this test, the method of procedure was changed to simulate more nearly what was thought to be the worst accelerating condition met with on the road; that is, the condition encountered when an automobile is allowed to coast along, as in traffic or down a grade, and then is accelerated up a slight grade. This was accomplished by adjusting the electrical load to a torque of 59 lb-ft. at 1000 r.p.m., and noting the position of the dynamometer controls. This was the position at which the controls were placed during each acceleration and was checked at the beginning of each day's run. Having made, as before, a power and fuel-consumption run at 600 r.p.m. with full throttle, the electrical load was then adjusted to a torque of 6.5 lb-ft. at 400 r.p.m. The throttle was then opened wide for acceleration and, at the same time, the dynamometer controls were placed in the position for acceleration as already described. The same procedure was then followed as in the previous method. This revised method is designated as Procedure No. 2.

Fig. 5 shows the electrical load applied to the *Z*-car engine during accelerations and also the power necessary to drive a car of the same model on a level road as determined by Prof. E. H. Lockwood, of Sheffield Scientific School, Yale University. It will be seen that the load applied in Procedure No. 1 simulates that of a car traveling up a slight grade at a constant speed and then accelerating; while Procedure No. 2, as mentioned,

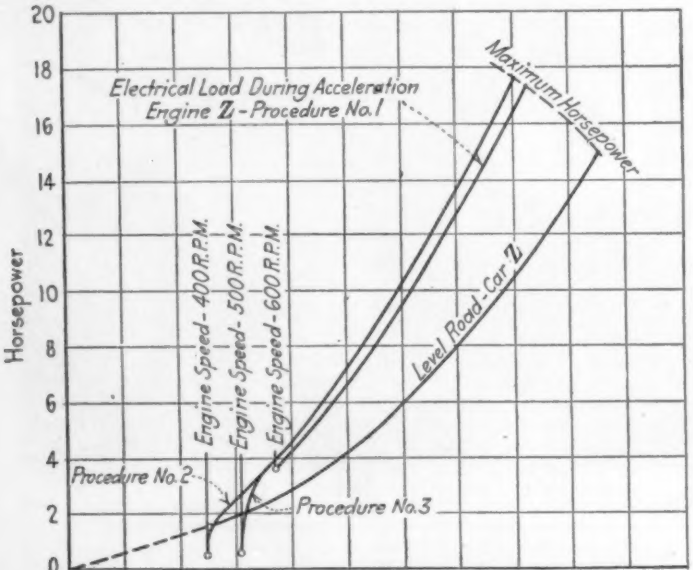

FIG. 5—ELECTRICAL LOAD APPLIED TO THE ENGINE OF CAR Z DURING THE ACCELERATION TESTS IN THE LABORATORY

The Load Applied in the Curve Marked "Procedure No. 1" Simulates That of a Car Traveling Up a Slight Grade and Then Accelerating, While That for Procedure No. 2 Simulates a Car Coasting with Less Load on the Engine Than Was Necessary Even for Level-Road Operation and Then Accelerating Up a Slight Grade. The Level-Road Curve Is Based upon Results Obtained by Prof. E. H. Lockwood at Sheffield Scientific School, Yale University

simulates that of a car coasting with less load on the engine than necessary, even for level-road operation, and then accelerating up a slight grade.

A preliminary test was then made with Procedure No. 2, comparing *B* and a much more-volatile fuel, domestic aviation-gasoline, under warm, medium and cold engine-conditions, to determine whether a measurable difference in acceleration as between these two could be obtained. The results showed better acceleration with the more-volatile fuel under each of these conditions. As in the previous test, better acceleration was obtained under cold conditions; also the maximum acceleration occurred very close to the carbureter setting for the maximum power.

A test was then made comparing *B* and *D* fuels under warm and under cold engine-conditions. This showed no difference in the acceleration as between *B* and *D* fuels under warm conditions, but a distinctly better acceleration for the *B* fuel under cold conditions. However, it was observed during this test that, under the cold conditions, the engine showed a tendency to miss while idling at 400 r.p.m. preparatory to an acceleration, and that this tendency appeared more pronounced while the *D* fuel was being used. As this tendency undoubtedly would introduce an error into the results, it was decided to make further accelerations from a speed of 500 r.p.m., at which speed it was found that the engine operated smoothly. This change is shown in Fig. 5 as Procedure No. 3.

Two complete sets of tests were then made comparing *B* and *D* fuels under warm, medium and cold engine-conditions. The results, while erratic, were similar to those obtained before except for the comparison of *B* and *D* fuels under cold-engine conditions. In this case, while one set of tests showed as before a better acceleration for the *B* fuel, the other set showed no difference in the acceleration as between the two fuels; but more of *D* fuel was required for the maximum acceleration than of *B*.

At this point it was found that the electrical load applied to the engine during an acceleration, by placing the dynamometer controls in the position to give a torque of 59 lb-ft. at 1000 r.p.m., as noted at the beginning of a day's run, was varying. This undoubtedly was due to changes in the temperature and, therefore, to the resistance of the loading grids. For this reason, in succeeding tests, the position of the controls was checked before each acceleration.

The next set of tests, as before, compared *B* and *D* fuels under warm, medium and cold engine-conditions. The data obtained during these tests were very consistent and gave every indication that a satisfactory method of procedure had been reached. The results are shown in Fig. 6. These agree with the previous general tendencies. Unfortunately, at this point, the explosion on Sept. 20, 1923, occurred at the Bureau of Standards and prevented further tests from being made for the present.

The general conclusions reached are that

(1) Under all conditions very nearly the same rate of acceleration is obtained with the *D* fuel as with the *B*, but under cold conditions more of the *D* fuel is required for maximum acceleration than of the *B*; which, however, is not as much more as the estimated possible production

(2) Maximum acceleration occurs at the carbureter setting giving the maximum power at 600 r.p.m. and full throttle

The tendency also was noted for the acceleration to

become greater as the temperatures were decreased. This, it must be remembered, is due largely to the greater power developed under these conditions, as shown by the torque curves in Fig. 6, and does not imply better fuel-utilization.

Two additional points that were brought out during the tests are of interest. Fig. 7 shows the speed of the engine during accelerations with lean, maximum-power and rich settings of the carbureter. This general result was typical of those noticed throughout the tests. It will be seen that there was an appreciable lag in the acceleration for the lean setting, as was to be expected. The comparison between the maximum-power and the rich settings, however, is interesting in view of the popular belief that a rich setting is necessary for maximum acceleration. It will be seen that, with the rich setting, it is a fact that this engine showed a greater initial-acceleration but that, for the full range of the engine speed, the greatest average-acceleration was obtained with the maximum-power setting.

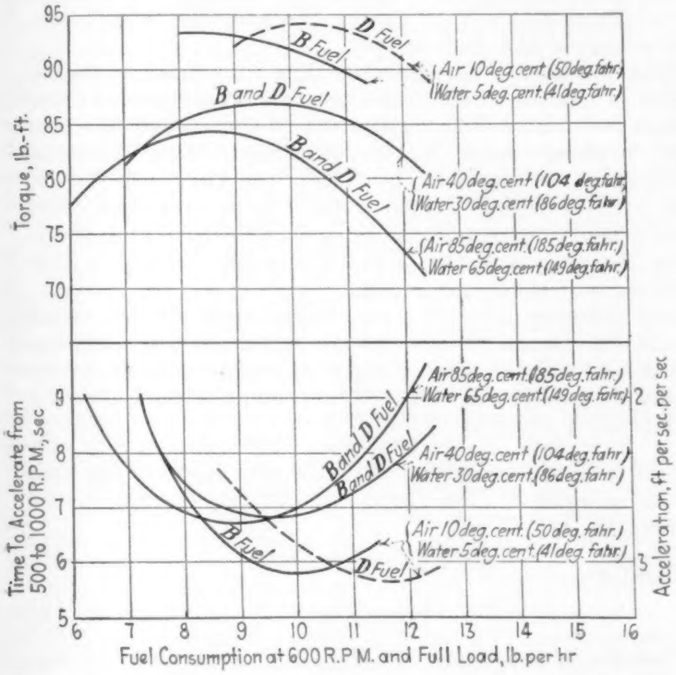

FIG. 6—TORQUE AND ACCELERATION RESULTS OBTAINED UNDER WARM, MEDIUM AND COLD-ENGINE CONDITIONS

The General Conclusions Reached Were That (*a*) under All Conditions Very Nearly the Same Rate of Acceleration Is Obtained with the *D* Fuel as with the *B*, but That under Cold Conditions More of the *D* Fuel Was Required for the Maximum Acceleration than of the *B*; This Difference However Is Not as Much More as the Estimated Production and (*b*) the Maximum Acceleration Occurs at the Carbureter Setting Giving the Maximum Power at 600 R.P.M. at Full Throttle. The Tendency Was Also Noted That the Acceleration Became Greater as the Temperature Decreased. This Does Not Imply Better Fuel-Utilization but Is Due Principally to the Greater Power Developed under These Conditions

Fig. 8 shows the other point of general interest. In this figure, curves are plotted showing the engine speed during accelerations from 400, 500, 600, 700 and 800 r.p.m., using the same loading in each case. Such curves should reveal any temporary influence such, for example, as might be exerted by an accelerating well. When an engine is accelerated from 400 r.p.m., one would expect the influence of the accelerating well to be shown at speeds immediately above 400 r.p.m.; whereas, its influence would appear immediately above 800 r.p.m. if the acceleration began at that speed. Any lag in the induction system would be manifested in much the same manner. Attention is directed to this type of test, as it promises to be of considerable value in any extensive study of acceleration. It has no special advantages as a basis of fuel comparisons and hence has been employed but little in this investigation.

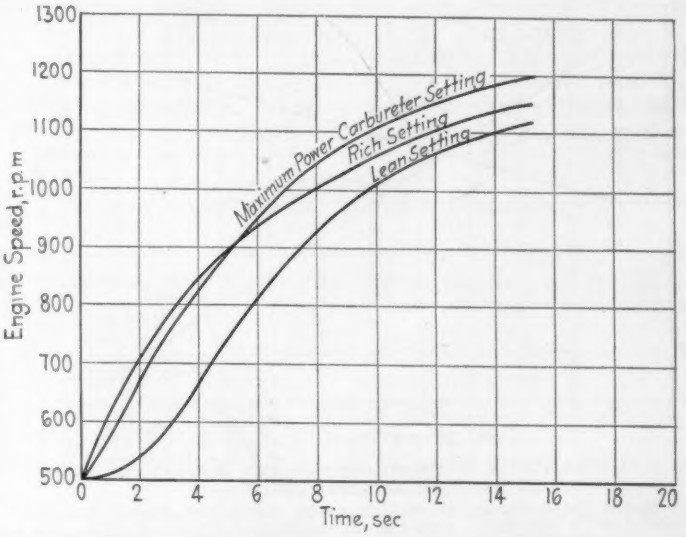

FIG. 7—TYPICAL ACCELERATION CURVES WITH LEAN, MAXIMUM-POWER AND RICH CARBURETER SETTINGS

As Was To Be Expected, an Appreciable Lag in the Acceleration for the Lean Setting Is Seen. The Comparison between the Maximum-Power and the Rich Settings Is Interesting Since It Shows That for the Rich Setting, the Engine Showed a Greater Initial-Acceleration While for the Full Range of Engine Speed, the Greatest Average-Acceleration Was Obtained with the Maximum-Power Setting. This Is Interesting in View of the Popular Belief That a Rich Setting Is Necessary To Obtain the Maximum Acceleration. The General Result Shown Is Typical of Those Noticed throughout the Tests

APPENDIX 1

DESIGN OF THE DISC USED TO SIMULATE THE INERTIA OF A CAR[8]

Mention is made in the foregoing paper of a steel disc, mounted on the end of a dynamometer armature-shaft,

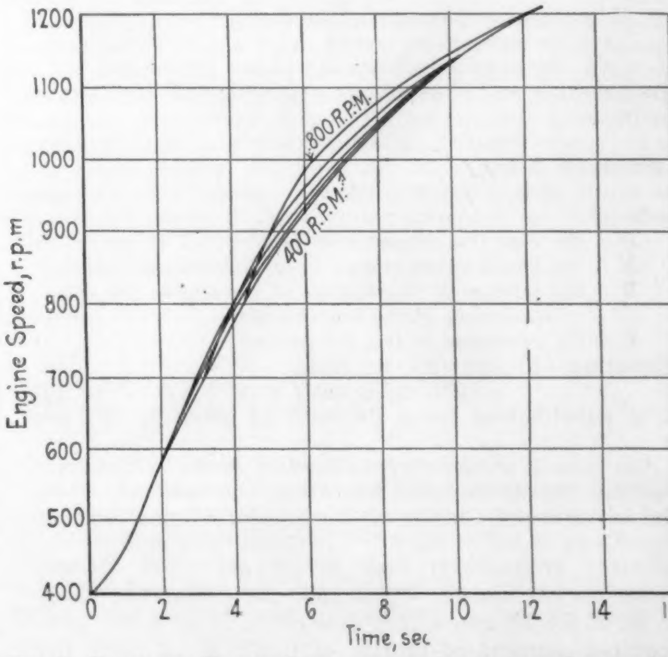

FIG. 8—CURVES OF ENGINE SPEED DURING ACCELERATIONS FROM 400, 500, 600, 700 AND 800 R.P.M., USING THE SAME LOADING AND THE SAME CARBURETER SETTING IN EACH CASE

These Curves Should Reveal Any Temporary Influence Such as That Exerted by an Accelerating Well for Example. This Type of Test, While It Promises To Be of Considerable Value in Any Extensive Study of Acceleration, Has No Special Advantage as a Basis of Fuel Comparisons

[8] Contributed by W. S. James, M.S.A.E., Physicist, Bureau of Standards, City of Washington.

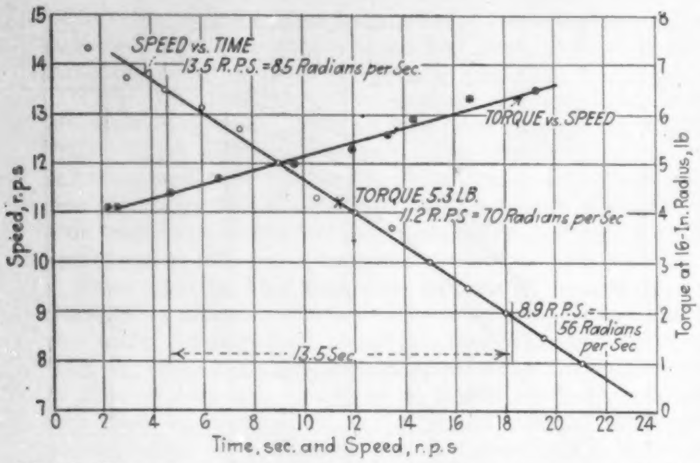

FIG. 9—EXPERIMENTAL DETERMINATION OF THE MOMENT OF INERTIA OF THE DYNAMOMETER ARMATURE

The Speed-Time Curve Shows That the Armature Speed Varied Linearly with the Time and the Torque-Speed Curve Verifies the Assumption That the Braking Torque Decreased Linearly with the Speed

of such dimensions that its inertia, added to that of the armature, equals the inertia of a car. Although the design of such a disc is not an unusual problem, it is felt that the inclusion of the design used in this instance will be of value for ready reference. The design was laid out as follows:

The kinetic energy of a car of stated weight that moves at a given linear velocity is

$$E = Wv^2/2g \tag{1}$$

where

E = the kinetic energy
g = 32.2 ft. per sec. per sec.
v = the linear velocity in feet per second
W = the car weight in pounds

The kinetic energy of a circular disc rotating at a stated angular velocity and having a given moment of inertia is

$$E_1 = (\omega^2 I)/2 \tag{2}$$

where

E_1 = the kinetic energy of the disc
I = the moment of inertia
ω = the angular velocity in radians per second

As the disc was to rotate at engine speed, its angular velocity is

$$\omega = 2\pi N \tag{3}$$

in which

$$N = VR/\pi D \tag{4}$$

where

D = the rear-tire diameter in feet
N = the speed of the engine in revolutions per second
R = the number of revolutions of the engine for one revolution of the rear wheels
V = the car speed in feet per second

Equating (1) and (2), we have

$$W v^2/2g = (\omega^2 I)/2 \tag{5}$$

and by substituting for ω its value as given by (3) and (4)

$$W v^2/2g = ([2\pi (VR/\pi D)]^2 I)/2 \tag{6}$$

Solving expression (6) to obtain the moment of inertia, in terms of pounds of force per foot per foot, we have

$$I = (1/4) \cdot (W/g) \cdot (D^2/R^2) \tag{7}$$

Taking a car weight, W, of 1800 lb., a rear-tire diameter, D, of 2.5 ft. and a rear-axle ratio, R, of 3.636, gave a required moment of inertia of 6.637 lb. of force per ft. per ft., from (7).

DYNAMOMETER-ARMATURE MOMENT OF INERTIA

In determining the dimensions of a disc to be mounted on the dynamometer shaft to give a total moment of inertia of the required amount, it was necessary to know the moment of inertia of the dynamometer armature. This was measured by disconnecting the dynamometer from the engine and speeding it up to about 2500 r.p.m., then opening the armature circuit and allowing the armature to slow down with a constant field-current flowing. When the armature was decelerating, it was found experimentally that the "braking force" decreased linearly with the speed, as would be expected, because, with a constant field-strength, the number of lines of force cut per second would vary directly with the armature speed. The braking force was measured at a given speed by setting the scale-beam at a definite torque and noting the speed at which the beam balanced, and the armature speed at fixed intervals for from 8 to 10 sec. before and after the scale-beam balanced. This was done with an electric chronograph that made records on a paper tape, but equally good results can be obtained with a chronometric tachometer by reading the average number of revolutions per minute during the previous 1 or 2 sec., according to the instrument.

Fig. 9 shows a speed-versus-time curve giving the results of one of these experiments. The torque-versus-speed curve gives the verification of the assumption that the "braking torque" decreased linearly with the armature speed. As can be seen from the curves in Fig. 9, the braking torque varied linearly with armature speed and armature speed varied linearly with time and, therefore, between any two armature speeds ω_1 and ω_2, expressed in radians per second.

An average force, F, can be assumed to be acting while the armature is rotating at an average angular-speed ω over the time t elapsing, while the armature speed drops from ω_1 to ω_2. Therefore, the work done by the braking force is

$$W = F\omega tr \tag{8}$$

where r is the radius of the scale-arm in feet, and this work is equal to the change in kinetic energy of the armature, or

$$E_2 = [(\omega_1^2 - \omega_2^2) I]/2 \tag{9}$$

Therefore, since $W = E_2$,

$$F\omega tr = [(\omega_1^2 - \omega_2^2) I]/2 \tag{10}$$

$$I = [(2F\omega tr)/(\omega_1^2 - \omega_2^2)] \tag{11}$$

For the experiments, the results of which are shown in Fig. 9, we have

F = 5.3 lb. of force
r = 1.33 ft.
t = 13.5 sec.
ω = 70.4 radians per sec.
ω_1 = 84.8 radians per sec.
ω_2 = 56.1 radians per sec.

Substituting these values in (11) and reducing, we have I = 3.3 lb. force per ft. per ft.

DISC AND FLANGES, MOMENT OF INERTIA

The average value of the determinants of the moment of inertia of the armature finally taken was 3.5. Therefore, as the desired moment of inertia was 6.637, the disc and its mounting flanges should have a moment of inertia of (6.637 — 3.500) = 3.137 lb. force per ft, per ft.

The moment of inertia of a circular disc about an axis through the center of rotation is

$$I = m r^2/2 \tag{12}$$

where

m = the mass of the disc in pounds
r = the outer radius in feet

Therefore,

$$I = (\rho t \pi r^2/g) \cdot (r^2/2) \tag{13}$$

where

g = 32.2 ft. per sec. per sec.

ρ = the weight of the metal in pounds per cubic foot
t = the thickness in feet

Assuming a value of 490 lb. per cu. ft., we have from (13)

$$I = (490/2g)\pi r^4 t \qquad (14)$$
$$= 23.9\, r^4 t$$

The main-disc thickness was decided as being ½ in. or 0.042 ft., the total thickness of the mounting flanges as being 2½ in. and the diameter of the mounting flanges as being 14 in.

The moment of inertia of the mounting flanges would be, from (14),

$$I = 23.00 \times 0.208 \times (0.583)^4$$
$$= 0.57 \text{ lb. force per ft. per ft.}$$

The required moment-of-inertia of the major disc is, therefore, $(3.137 - 0.570) = 2.567$ lb. force per ft. per ft. Hence, if its thickness is to be ½ in., its radius will be

$$r = \sqrt[4]{(I/23.9\, t)}$$
$$= \sqrt[4]{(2.567/23.900 \times 0.042)}$$
$$= 1.2646 \text{ ft.}$$
$$= 15.175 \text{ in.}$$

Therefore, the major disc will be 30.35 in. in diameter and ½ in. thick.

THE FRENCH FRANC

CERTAIN immediate causes for a decline in the international value of a country's currency are well known, causes which of course hark back to conditions within the country itself, but which first and most directly and violently affect the status of the country's account with the rest of the world. Chief among these causes, it goes without saying, is a fundamentally unbalanced condition of the country's trade with other countries; merchandise imports the value of which is steadily in excess of the value of the merchandise exports to an extent that cannot be provided for by invisible items of international account in the country's favor. When this condition exists in respect of a given country, an external depreciation of its currency in terms of other moneys is inevitably produced by the continuous struggle to obtain the wherewithal in these other moneys to meet the bill for the country's absolute excess of imports. A second cause having a similar effect, though operating less directly, is an inflation of a country's currency, not necessarily in relation to the gold reserve behind it, but rather in relation to the volume of business for which the currency is employed. Such inflation, of course, actually decreases the intrinsic value of the currency, its purchasing power in goods and services at home as well as abroad; and this diminution of the intrinsic value of the currency cannot fail to be reflected in the basis of its exchange for other moneys, the intrinsic value of which has not been correspondingly decreased. Finally, the international value of a country's currency may be reduced in terms of other currencies if the country, whether through its government or through its private citizens or through both, has incurred abroad a sum total of indebtedness so great that the country's productive industries are inadequate to provide the wherewithal to meet the interest and amortization of such indebtedness.

The recent severe decline of the exchange value of the franc cannot possibly be accounted for upon the ground of a fundamentally unbalanced state of the commercial and other interchanges of France with the rest of the world. The balance in favor of France on her total interchanges with other countries is a powerful influence tending to increase the value of the French currency in international exchange transactions.

The volume of the currency in circulation in France, instead of increasing progressively during the post-war period, is actually smaller than it was nearly 3½ years ago. No inflation of the French currency has occurred; and the severe depreciation of the franc abroad, attended by a lesser sympathetic domestic depreciation, cannot possibly be attributed to this cause.

The war indebtedness of France to the United States and Great Britain combined is enormous, some $6,500,000,000 all told. But the French Government has as yet practically not undertaken the settlement of this indebtedness or even the payment of interest upon it. Certainly no forced buying of foreign moneys by France on this account has occurred; and so far as the foreign debts of France and her citizens in ordinary course are concerned, ample means to meet them are unquestionably being provided by the productive industries of the country.

It is our opinion that no substantial and permanent reason for the decline of the franc to its present low level exists. The intrinsic value of the French franc, upon the basis of the relation between the amount of currency outstanding in France and the volume of business for which it is required, is now approximately 7 cents in United States money; that is, in gold. And we entertain not the slightest doubt that the market value of the franc will in due course return to this intrinsic value, if the French currency is not inflated.—A. R. Marsh in *Economic World.*

THE SCIENTIFIC MIND

PROVISIONALLY, with some vagueness and confusion, "science" is distinguished from those supposed *a priori* deductions and corresponding universal or necessitated mental processes, grouped under the head of philosophy or dubbed metaphysics. Accepting, likewise vaguely and provisionally, this separation of science from philosophy, we hasten to observe that science also is one of those words which cover much that is diverse. Science, the direct, systematic and rational investigation of nature, has followed many ways into many fields and has been led by many motives. Though one should conceive a formula broad enough to hold the basic method or rationale of all scientific procedure, nevertheless, the faces and surfaces of actual scientific processes differ.

Science is an endeavor to rationalize observed phenomena and "simplify" them. The testimony of the senses and a reliance upon experience, somehow tested, compared and logically adjusted, are the foundation. The method of the scientist lies also in his choice of facts, his choice of significant, constantly recurring, rather than meaningless sporadic, facts; the facts that most readily lend themselves to generalization or simplification in a descriptive statement, which is the statement of a law.

It may be that the fundamental laws of thermodynamics, the conservation of energy and Carnot's principle of its degradation, will endure; but the stable maintenance of mass is no longer accepted for bodies moving at high velocities; and the tendency is to identify mass with energy and energy with electricity.—H. O. Taylor.

Service

By W. L. Wise[1] DAYTON SERVICE MEETING PAPER

APPLICATIONS of the basic principles of "service," as developed by the company represented by the author, are suggested for promulgation in the automotive industry, following a statement of the methods employed in servicing cash-registers. Six very important considerations in the sale of service to the user are specified, and the manner in which the service-men are educated for this work by the company is described, including a list of the subjects in which training is given. Periodical inspections are advocated and maintained whenever possible; repair prices are treated and service-station policies are outlined. Nine specific things that a service-man must sell are enumerated, and the plea is made that he be taught how to sell them intelligently. The conclusion is that only good service can be satisfactorily sold.

IN dealing with this question of service, it is recognized that National cash-register service and the service of automobile companies differ in many respects. However, the one important fact remains that any service is offered for the benefit of the user; and the user today is more concerned over the value he receives for his dollar than ever before.

Every manufacturer has certain guiding principles and maintains certain high ideals in his business. Were the officers of the institution able in every case to meet the individual user, the company would be in a very happy position. It would then be assured that each user understood the policy of the company, and the company itself could be sure that every effort had been made to satisfy the user's wants. Unfortunately, such a condition cannot be reached, and it is up to the different manufacturers to depend on someone else to meet their users and to explain their policies. In most cases it is the service-man who represents the company. The company therefore becomes just as big or just as small as the individual service-man. He may understand thoroughly the ideals of the company or he may be indifferent. The user receives the same impression of the company that the service-man holds. One thing is certain, in the question of selling, whether it be service or anything else: the salesman can only impress the user with what he believes. Unless he believes your service is good, that your car is worthwhile and that your policies are right, you can rest assured he will not impress your ideals and policies on the user.

Perhaps the most important thing that any business sells is its service. Nothing can be of greater value. For instance, you, in the automobile business, are selling so many miles of service and not an automobile. Of course, there are many such incidentals as easy riding, low gasoline-consumption and comfort, but in the final analysis the user is buying so many miles of service. He may not decide to take advantage of the full period of usefulness, but he does want to know that when he decides to trade or sell his car, it will have a certain number of service-miles to run. These service-miles establish its trade-in or resale value.

Service means carrying out the terms we have made and the obligations we have taken upon ourselves in selling our product. The right to this service is included in the price of the article when it is sold. In the sale of service several considerations are very important:

(1) The company must school its agents in its service policies
(2) The company must establish its reputation with its service representatives
(3) The company must try to sell its service and its service-men's work to its users
(4) The user must be taught his obligation to the mechanism he has bought
(5) The service-man must be able to sell his service to the user so that, after the job is completed, the bill is paid willingly and the user maintains a friendly disposition toward the company and retains a high regard for the mechanism he is using

Everyone connected with service has had to deal with users who claimed certain concessions had been offered at the time of the sale. There is but one way to cure this. Educate your agents on the provisions of your guarantee and see that they are capable of selling both it and your service policies to their prospects. How much better it would be for the salesman to speak enthusiastically of the quality of your service, instead of having him sidestep any reference to it, or, if he does mention it, misrepresent it by either omission or commission.

EDUCATION OF REPAIRMEN

One of the first things we try to teach a repair student is that he is working for a good company and can always be proud of being engaged in National cash-register repair-work. We also try to impress him with the quality of the product and, in turn, dwell upon his obligation to maintain this reputation. It is important that he feel that his work has a definite bearing on the future progress of the company, and that so far as his individual territory is concerned the attitude of the users toward National cash-registers is much a question of their attitude toward the service they are receiving. If these users are to be of any assistance in extending the use of National cash-registers in their particular community, he has a great responsibility in keeping them satisfied.

We take particular pains to explain the company's reason for the different decisions that affect his dealings with either the user or the company. Before he is permitted to approach a user to explain our periodical inspection plan, he must make a number of approaches to his instructors. If he seems slow in accepting or explaining the company's policy, he is given another explanation. We are constantly impressing the men in the field with the idea of convincing themselves before trying to convince the users. The man who cannot feel whole-heartedly that the kind of service his company is advocating is right is in the wrong business. The service-man is either making or breaking his company's reputation. We also have our men understand that the company vouches for their ability and honesty. The company goes further and advertises the feeling it has toward its service-men.

Every National cash-register that leaves the factory has a sticker pasted in the cash-drawer, which reads as follows and is signed by the president of the Company:

[1] Service manager, National Cash Register Co., Dayton, Ohio.

To the Purchaser:—It is the duty of the agent who sells this register to give you service until you have thoroughly mastered the details of the use of the register. Should you not understand its use thoroughly, please write me direct.

Further, it contains a facsimile of a repairman's identification-card, with an explanation of the care used in selecting our repairmen, the training they receive and why the user should rely only on accredited National cash-register service. In our direction-books we again emphasize the importance of having trained National cash-register repairmen do the work. We supply our men with stickers to be placed in the cash-drawers of users' machines. These stickers advertise National register service and also give the agency address. We try to leave the thought with the customer that we are proud of our service and of our service-men. A company can be proud of its service only when it has spared no effort to make it the best. Our entire effort in selling service is to make the customer appreciate the need for National cash-register service and to make the repairman worthy of giving this service. The repairman is also taught that he is not treating the user fairly unless he teaches the user the value of our service.

Our experience has taught us that 50 per cent of the training of the repairman is mechanical, the other 50 per cent relating to the treatment of the user and the sale of the service. The commercial training of a repairman progresses with his mechanical training. We appreciate that the repairman experiences all the "grief." He must be taught to overlook the troubles he is experiencing, so that he can meet the customer with a cheerful disposition. He must be taught always to think well and speak well of his product, to keep his balance in time of emergency, to sell his user on how small and unimportant the trouble is, then how big a job he can offer and to work for a user and to consider him his boss; for in the last analysis it is he who is keeping the factory chimney smoking. Further, the repairman is taught to take pride in the betterment of his product by giving the company the value of his suggestions.

We believe that it is more practicable for a student to learn from the experiences of others than from his own. The latter is too slow a process and causes dissatisfaction among our users. For this reason we gather together all the information we can to give to the man before he goes to the field. We endeavor to put into his mouth the reasons the company is guided by certain principles. We furnish him a service manual. We try to set up scenes in our commercial classes that correspond to those he will meet in his work in the field. He is coached by experienced repairmen who have profited by not only their own experiences but by what they have gained from others. Each man must pass an examination on his commercial ability before he is sent to the field. His training takes up such subjects as:

(1) Planning his work
(2) Records that must be kept
(3) Answering calls and rendering service over the telephone
(4) Installation of registers, both mechanical and functional
(5) The care of registers from the user's standpoint
(6) Selling a user on periodical inspection
(7) How to collect expense on repair calls
(8) How to estimate work
(9) How to explain an estimate to the user
(10) Explanation of our guarantee
(11) Meeting the user's objections
(12) How to explain the quality of our service
(13) The necessity of using our parts
(14) The answers to a user's objections on any phase of a repairman's work

Analysis of Complaints

In our analysis of complaints, we find a large proportion of the trouble is due to neglect or carelessness. To eliminate this as much as possible, the user must be taught, first, the proper use of the mechanism and the care it should receive to maintain its efficiency; second, that a register, like any other mechanical device, begins to wear as soon as it is put into use and that, to hold this wear to the minimum, it must be gone over periodically by one of our trained repairmen. It is not always an easy matter to sell the user on this periodical inspection. First of all, in the operation of the register, he sees only a certain number of functions that he obtains and is entirely unfamiliar with the mechanism required to bring about these results. Naturally, on the other hand, it is the problem of the company to see that the lives of its registers are just as long as possible. We have to guard the user against neglecting the machine because, when we sold him a register, we promised it would last a business lifetime, and it is incumbent upon us to use every effort to see that he gets the maximum amount of use.

Periodical Inspection

It is recognized that to leave the selling of periodical oiling, inspecting and adjusting entirely up to the repairman places him in a position of one seeking work rather than in the position of a man who is offering some real benefit. To eliminate such a feeling on the part of the user the repairman is taught to say, "My company advocates this," instead of, "I suggest it." To assist him, we have written our instruction-books to him in such a way that they can be shown to the user in the approach. In fact, we have found literature such as bulletins and service letters of material advantage in explaining to the users the company's ideas on service.

It is our endeavor to give a user a true understanding of our service policy so that he can check our repairman's work. The latter can become our inspector only after he has acquired a true idea of what he is to inspect. We assume that a user will appreciate what is being done in his behalf; also that he will be more likely to take the manufacturer's word than that of any other. For, after all, the manufacturer is the one who profits or loses through the opinion of its users. Realizing that service is much a matter of confidence, we have our repairmen offer to do the work in the customer's store, under his direct supervision. Of course, where the job is such as to make it necessary to go into the repair department, we expect the repairman to be able to sell the customer on this necessity.

Remembering that our service has a direct bearing on the cost per year, and that the cost per year and long life together determine values at any period, we take every precaution to see that no repairman endeavors to do any more work than is essential. To be assured of this, we teach him in our repair school the essentials of a mechanical job, measured in terms of factory standards. We train him how to inspect a register to find out what is wrong with it. We outline a systematic procedure. We also have this written-up in an inspection-book for reference at any time.

Repair Prices

The company sets the prices for the repairman's work and for the parts, and we make it a part of our service

approach to let the user understand that these prices are fixed at Dayton and that we endeavor to maintain service efficiency through our field examinations. Also, we check the individual job from our mechanic's report, which specifies the trouble and its causes and the remedy that he applied. If we find his reports are about the average, we do not question them. If, in our estimation, the repairman is not measuring up to standard performance, a refund is given to the customer and the repairman either receives further instructions from one of our field-men or is brought to the factory for a review.

Our prices per hour include whatever tools are necessary. If it is a buffing or grinding job, the repairman is not to charge for hand-buffing or filing. We try to make this plain in our service literature. We also furnish in pamphlet form a list of the duties and obligations of a repairman. He is asked to submit this to the user to establish that bond of confidence which is necessary in dealing with service.

No man is expected to give an estimate for a job until he has thoroughly investigated to find out just what work is necessary and what parts need to be replaced. If it is a job that should be handled in the repair department, the user is given to understand that he will be furnished a further estimate covering all the work to be done and that he will be shown what adjustments are necessary on the register, and what new parts are to be added, the customer's consent being obtained before the repairman proceeds with the work. We feel that the man who is spending the money has a right to know how every cent of it is to be spent, and this not from a letter or visit of a repairman, but from an actual examination of the machine.

We encourage our users to visit the repair department. We try in every way to eliminate the "No-Admittance" idea. We try to instill in every repairman the thought that the longer the life a user obtains from his register and the cheaper the service cost is, the better will be the future of the National cash-register business. We aim to save a user annoyance and expense by explaining the reasons for his troubles.

Estimates are made as accurately as possible. However, the user is given to understand that an estimate is purely an estimate and that we will charge only for time and material. If the work can be done for less than the estimate, it will be done; if the expense is more than the estimate, we expect the customer to pay. We try to leave the impression with him that our interest is not in piling up repair work but in keeping his register going at the least possible cost; and, further, that the user who takes care of his register can look for small repair-bills, whereas, if the register is neglected or abused, the bill will be correspondingly increased.

If our service is offered as the company expects it to be sold, there is no reason why any user of a National cash-register should rely on an outsider for service. We have these advantages:

(1) Trained repairmen who have spent from 12 to 15 months in our training-school

(2) We learn from a review of our field troubles what is likely to develop in our product. Every manufacturer knows better than anybody else the weaknesses and abuse that his product must withstand. Consequently, we can fortify our repairmen on these adjustments

(3) We are constantly improving mechanisms and methods. Many of these improvements apply to registers already in the field. Our training both at the factory and in the field is offered with the idea of giving our users the advantage of the latest factory developments

(4) Use of National Cash Register parts manufactured by us. We have $3,000,000 invested in tools and a large investment in special machines. No other parts for National cash-registers are so accurate as ours, nor is as much attention given by the outsider to the selection of the material for these parts as we give. Modern tools and modern machinery enable us to offer National cash-register parts at the lowest price consistent with good workmanship

(5) Our service reflects the interest of the manufacturer in the quality and life of the product. This is most important

We feel that, if our repairmen thoroughly understand and realize the truth of these five points, we shall have no difficulty in selling our users on the kind of service that is best for their interest. Perhaps it will be argued that this selling of service takes time. This is true, but time spent among our users wins their confidence, and this means a reliance on us for future work. It would be a mighty big thing for the National cash-register business, as well as for the automobile industry in its field, to have all of its users thinking well of its product and looking toward the manufacturer entirely for service. How often has the manufacturer been blamed for faulty construction when, in reality, the fault lay in either the ignorance or carelessness of the repairman.

The repairmen are instructed to collect bills at the time the repair work is finished, because this assures explanation and acceptance of the charges.

The service-men meet periodically in the field to talk over service literature sent out by the company and to bring up their troubles from both mechanical and commercial standpoints. New devices are shown and explained, for our first thought is to make our service good and, secondly, to see that our repairmen understand that it is good, so that when they approach a customer they shall be in a position to sell it. In these conventions the men are taught the strong points of the mechanisms of different types of register. They must know the value of the different features and be able to talk the user's system in terms of his register; in other words, they must be able to satisfy the user with his purchase and not discourage him by an effort to sell him something else.

Automobile Service-Station Policy

As a general rule, manufacturers are careful in the selection of material for their product. Careful research is made to see that the parts correlate and harmonize with each other, yet in my limited experience as an automobile user, I have often found service-men suggesting a different type of carbureter, magneto or some other accessory they may have on hand. This raises a question in the mind of the user as to the quality of the original product. Reselling is just as important as selling. Why not enthuse your service department over it? Why not teach the men the merits of the different parts? Why not spend a few hours each month in acquainting them with the best methods of meeting customers' objections and explaining the product? Why not school them in telling the users what causes their particular troubles and showing them how to avoid them in the future?

Run your service garages to take care of your users and not as a source of additional revenue. Have it understood that in your organization your profit is made in

(*Concluded on p.* 318)

Airplane-Engine Designing for Reliability

By GEORGE J. MEAD[1]

ANNUAL MEETING PAPER

Illustrated with PHOTOGRAPHS AND DRAWINGS

PRECISE and accurate engineering is necessary to increase the reliability of airplane engines while at the same time decreasing the weight. Unreliability inspires fear and the former practice of merely making weak parts heavier cannot be tolerated in aircraft because excessive weight reduces the carrying capacity and consequently the range of action. With these points in view, recent improvements have produced an aircraft engine that will operate for longer periods at higher mean effective pressures than any other type of internal combustion engine. Several types weighing less than 2½ lb. per hp. have run for periods of from 200 to 300 hr. with but little attention. The Wright E-4, with the same crankcase assembly, the cylinders only being changed, ran for 572 hr. without attention of any kind. Compared with the original Model A, built 8 years ago, the present engine with approximately the same weight and same displacement develops one-third more power, operates at 24 per cent more speed and has 3000 per cent greater durability.

During the war, exhaust-valves, connecting-rod big-end bearings and spark-plugs gave the most trouble. In cylinder construction three difficulties presented themselves: (*a*) the valves warped and burned, (*b*) the valve-seats did not remain true and (*c*) in long runs the valves hammered into the seats so that the tappet clearance was lost and the valves were held open. The various steps that were taken leading up to the present type of cylinder, the adoption of tulip-shaped silchrome steel valves, the use of copper-lead-tin bearings without babbitt lining, and the difficulties encountered in obtaining satisfactory ignition equipment are described in detail. Carbureter development is said to have also progressed. Lack of crankcase rigidity in Liberty engines caused broken camshaft-housings and resulted in failures of the timing-gear. Although the modern shaft transmits 55 per cent more power, its weight is only 17 per cent greater. When running at 350 instead of 420 hp. the Liberty engine has a comparatively long life and weighs 2½ lb. per hp. Duration running has shown that engines weighing less than 2 lb. per hp. are literally torn apart. Refinement of details of the 1947-cu. in. 60-deg. V-type 12-cylinder Wright T-3 engine has enabled it to be used satisfactorily at speeds greater than 2200 r.p.m. and to develop 750 hp. with approximately 140 lb. mean effective pressure at 20 per cent less weight per horsepower than that of the original engine.

In applying the facts learned from experience to future design, it appears that the points which should receive the greatest consideration are simplicity of design and correct distribution of the proper material, rigidity, dimensional errors and the use of the correct factors of safety, the effect of fatigue, the operating conditions under which the powerplant will be expected to function, lubrication and the storage conditions that will make it possible to protect the engine from rust, both internally and externally. Test results frequently show the need of features not apparent on the drafting-board, such as accessibility for inspection and adjustment, but care must be taken in making deductions from test data that may be inaccurate or incomplete. The performance of production engines is the only reliable criterion of the success of a particular design. The importance of the use of good materials is emphasized, as well as accurate inspection and close tolerances. To secure the best results in operation, specified conditions must be complied with, such as the temperatures of water and oil, maximum engine speed and minimum oil pressure; the best mechanism will not operate satisfactorily under adverse conditions.

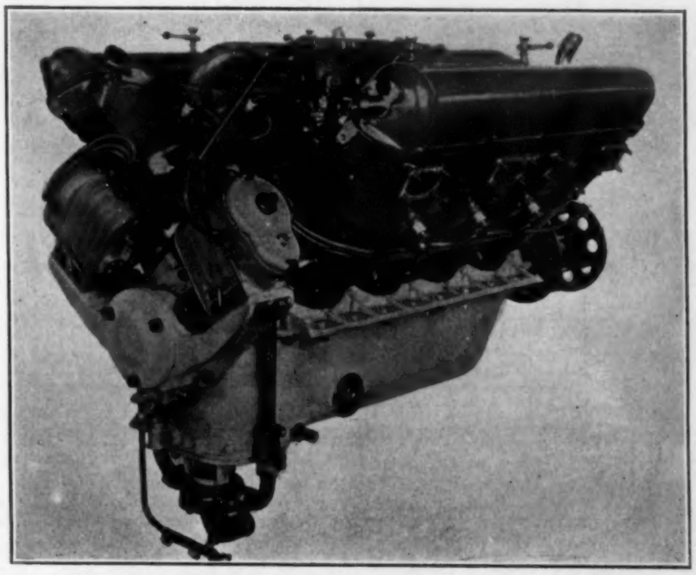

FIG. 1—THE WRIGHT E-4 AIRCRAFT ENGINE

This Eight-Cylinder Engine Was Run for 310 Hr. and Developed 122 Lb. Mean Effective Pressure at 1800 R.P.M. without Dismantling the Cylinder Block. Only Minor External Adjustments and Repairs, None of Which Would Have Caused an Airplane To Come Down During an Ordinary Flight, Were Necessary during This Period. Practically Everything about This Engine, except the Cylinders, Had a Total of 572 Hr. at Full Power without Attention of Any Kind. In Other Words the Cylinders Were Operated Long Enough To Have Carried an Airplane 31,000 Miles at a Speed of 100 M.P.H., and the Other Parts Had Been in Operation Long Enough To Have Carried an Airplane 57,200 Miles at the Same Speed without Any Attention

IT is unnecessary to dwell on the importance of the reliability of aircraft powerplants. No single thing is more responsible for the retardation of commercial aviation than fear, and fear is caused by unreliable aircraft. For this reason, a large amount of recent powerplant development has had for its object the securing of greater reliability. A fallacy that weight is synonymous with strength prevails, and that if a reliable engine is desired it is necessary only to make it heavy. In case of failure, it used to be common engineering practice to make the whole design heavier with the hope that the weak points would thereby be eliminated. This practice cannot be tolerated in aircraft, as excessive weight reduces the carrying capacity of a machine and consequently its range of action. As a matter of fact, mere weight has very little bearing on reliability and, in

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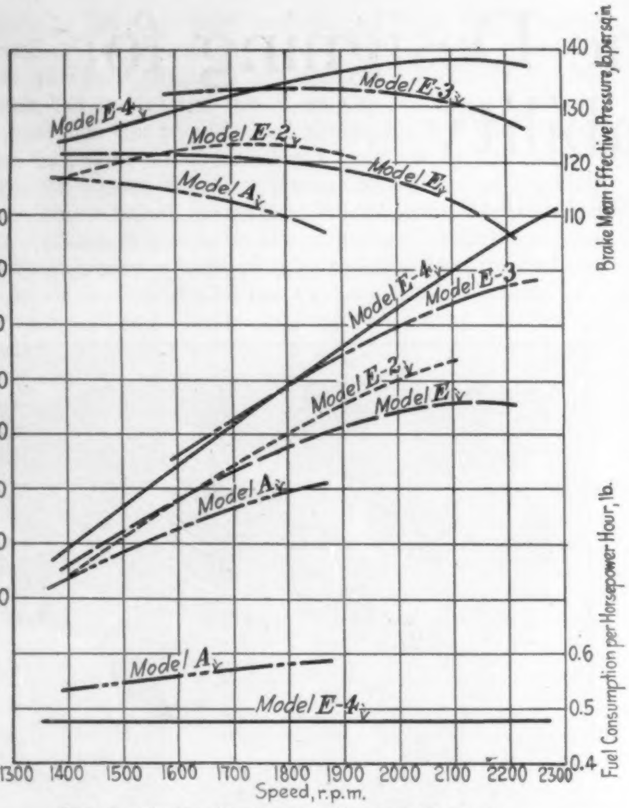

FIG. 2—POWER CURVES OF VARIOUS ENGINES
These Curves Present Relative Performance Data and Show the Development Work Done by the Wright Aeronautical Corporation on One Type of Engine from 1916 to 1923

many cases, particularly in reciprocating parts, defeats the object desired. This means that precise and accurate engineering is necessary. As a result, a modern aircraft engine will operate for longer periods at higher mean effective pressures, without attention, than any other type of internal-combustion engine. Since reliability, which in this case is practically synonymous with durability, is of so great importance, considerable experience has been gained in developing light powerplants having this characteristic. It is proposed to take up some of the interesting phases of this work, dwelling upon construction and proper operation to some extent, as well as upon design, because they are equally essential items. As practically all our experiences have a direct bearing on automotive work, it is hoped that this paper will prove of general interest.

RECENT PERFORMANCES

Marked advances have been made in aviation powerplant reliability during the last few years. Two types of 8-cylinder V-type water-cooled engines and one 12-cylinder V-type, all weighing less than 2½ lb. per hp., have run for periods of from 200 to 300 hr. with but little attention; and one 6-cylinder, dirigible-type engine, weighing 3¼ lb. per hp., has been operated for 300 hr. without disassembling. The Wright E-4 engine shown in Fig. 1, one of the 8-cylinder models mentioned, was run for 310 hr., developing 122 lb. mean effective pressure at 1800 r.p.m., without dismantling the cylinder blocks. This is equivalent to 31,000 miles at 100 m.p.h. Only minor external adjustments and repairs were necessary during this period, none of which would have caused an airplane to come down during an ordinary flight. This same engine in previous tests had been run for 250 hr. with experimental cylinders of a different design. The crankcase assembly, in fact, practically everything except the cylinders, had a total of 572 hr. at full power without attention of any kind. In other words, these parts had been in operation long enough to have carried an airplane 57,200 miles at the rate of 100 m.p.h. The original engines of this type, called Model A, built 8 years ago, would run with difficulty for 10 hr. at 1450 r.p.m. with full throttle, developing 114 lb. mean effective pressure. Not only does the present model with the same displacement develop one-third more power in service with approximately the same total weight, but it is operating at 24 per cent greater speed and with 3000 per cent greater durability. The original Model A engines developed a maximum of 175 hp. at 1800 r.p.m., whereas the latest model develops a maximum of 285 hp. at 2300 r.p.m., a gain of 63 per cent. Such results are not obtained rapidly but follow from developing a basically sound design. These figures are given simply to indicate in a general but accurate way the progress that has been made. The power curves shown in Fig. 2 illustrate the progressive development of this particular engine. A comparison of Figs. 1 and 3 shows some of the changes that have taken place in its external appearance.

LESSONS LEARNED FROM DURATION TESTING

How were these results accomplished and what application have they to future design? These questions will now be taken up, as it is felt that a discussion of them will indicate the important developments that have occurred.

War-time engines had the most trouble with exhaust-valves, connecting-rod big-end bearings and ignition. To overcome these difficulties, a series of tests was conducted with a Wright E-2 engine which is a 90-deg. V-type 8-cylinder water-cooled model, having a displacement of 718 cu. in. This was the first post-war engine, and in it certain changes had been made with the hope of rectifying the valve trouble. The cylinder construction is shown in the upper right corner of Fig. 4 and consists of flanged closed-end steel sleeves, threaded into an aluminum block, four cylinders in each assembly. In this case, the steel heads were approximately ½ in. thick to prevent deflection, and water was carried completely around the exhaust-valve seats. The valves themselves were guided by bushings in the cylinder block but were seated in the steel cylinder-heads. Water was carried in

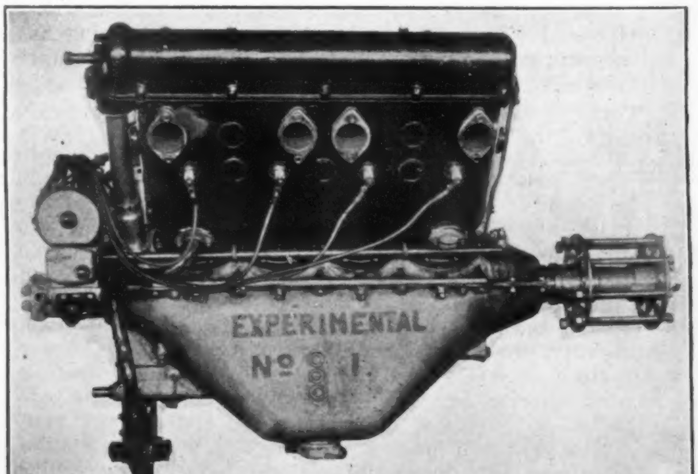

FIG. 3—THE ORIGINAL WRIGHT TYPE E AIRCRAFT ENGINE
A Comparison of This Engine with That Shown in Fig. 1 Will Indicate Some of the Changes in the External Appearance of This Type of Engine That Have Taken Place as the Result of Development Work

the aluminum block, but did not come into direct contact with the cylinder sleeves. It was found that this construction was somewhat better than the previous one but could not be operated for more than 20 to 30 hr. at full throttle without regrinding the valves. Another type of cylinder, illustrated in the lower left corner, was tried in the E-3 engine without any particular increase in

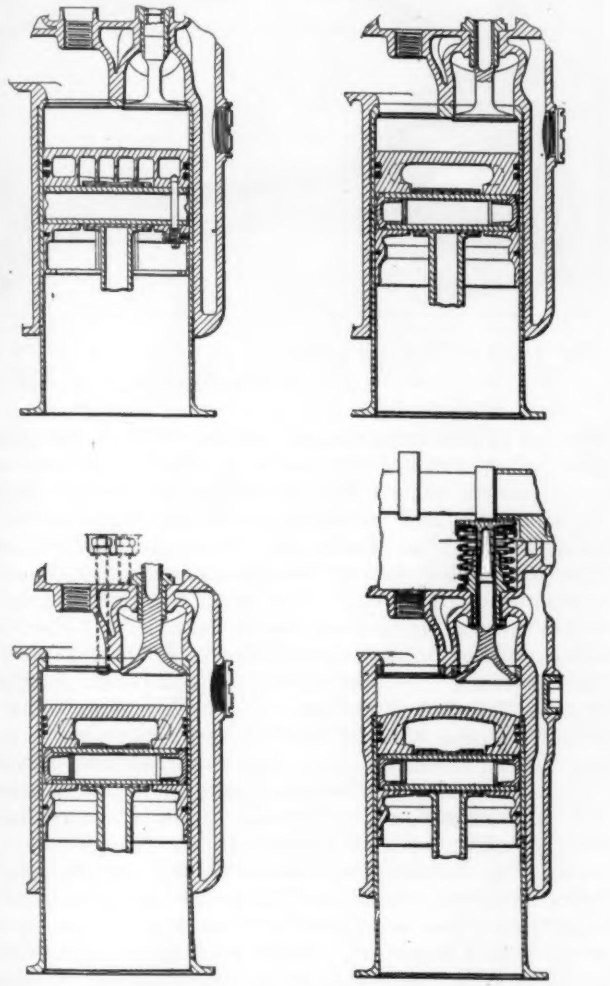

FIG. 4—CROSS-SECTION SHOWING THE CYLINDER DEVELOPMENT IN THE WRIGHT AIRCRAFT ENGINE

The Cylinder of the Original Model A Engine That Developed a Maximum of 175 Hp. at 1800 R.P.M. Is Shown in the Upper Corner. At the Upper Right Corner Is the Cylinder of the First Post-War Engine, the E-2. This Was an Eight-Cylinder 90-Deg. V-Type Water-Cooled Engine Having a Cylinder Displacement of 718 Cu. In. The Cylinder Construction Consisted of Flanged Closed-End Steel Sleeves, Threaded into an Aluminum Block; It Could Not Be Operated for More Than from 20 to 30 Hr. at Full Throttle without Valve Grinding. The Cylinder Construction That Was Used on the E-3 Engine Is Shown at the Lower Left Corner. This Construction Was Similar to That Used on the E-2 Engine, except That the Threaded Steel Sleeves Were Omitted and Plain Sleeves, Which Were Held in Position in the Block by Two Studs per Cylinder That Passed through the Top of the Block, Were Used Instead. These Sleeves Were Shrunk into Position at Assembly. This Construction Was Not as Good Theoretically from the Cooling Standpoint as the Threaded Type Since Less Surface for the Dissipation of the Heat Was Available. The Cylinder Design of the E-4 Engine Shown in the Lower Right Corner Includes an Aluminum Combustion-Chamber and Cylinder Sleeve That Are Open Ended and Threaded for a Short Portion at the Top

performance. This construction was similar to the one just described, except that the threaded steel sleeves were omitted and plain sleeves were used instead, being held in position in the blocks by two studs per cylinder that passed through the top of the block, as shown. These sleeves were shrunk into position at the time of assembling. This construction was not so good theoretically from the cooling standpoint as was the threaded

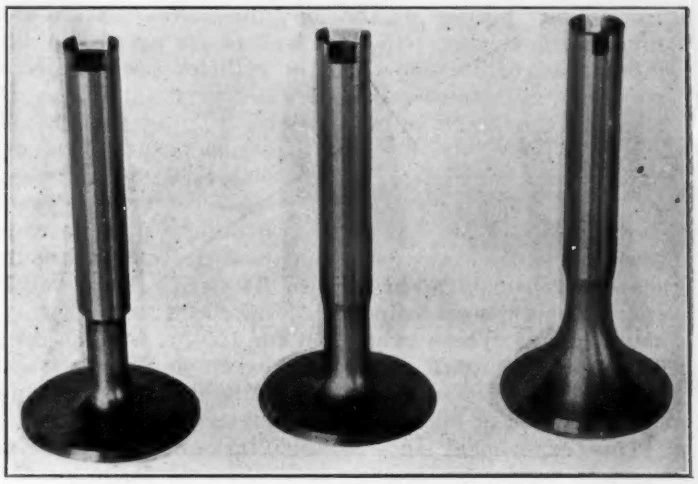

FIG. 5—EVOLUTION IN VALVE DESIGN

From Left to Right These Are an Early Type of Tungsten Valve, a Later Design of Chromium Steel Valve and the Most Recent Type of Silchrome Steel Valve with a Tulip-Shape Head. After a 310-Hr. Test of the Last Valve No Measurable Difference in the Tappet Clearance Could Be Detected and the Power Developed by the Cylinders Was Slightly More Than at the Start of the Test

type, owing to the fact that less surface was available for the dissipation of heat. On the other hand, it was possible to grind both the sleeves and the holes in the block, so that in the E-3 type more actual contact between the sleeve and the block was obtained. Moreover, this design is much easier to manufacture.

Three serious difficulties presented themselves with both these constructions, namely, that (*a*) the valves were inclined to warp and, consequently, to burn, (*b*) the valve seats did not remain true and (*c*) the valves in the long runs often hammered into the steel seats to such an extent that the tappet clearance was entirely lost and the valves were held open by the backs of the cams. Incidentally, the steel cylinders would allow only approximately 110 lb. mean effective pressure when operating on aviation gasoline, without serious detonation. It was obvious that a different valve, as well as seat material, had to be obtained, and in some way a more efficiently cooled combustion-chamber should be provided. To accomplish these things, the E-4 cylinder design shown in the lower right corner of Fig. 4 was developed. This design provides an aluminum combustion-chamber; the cylinder sleeves are open-ended and are only threaded

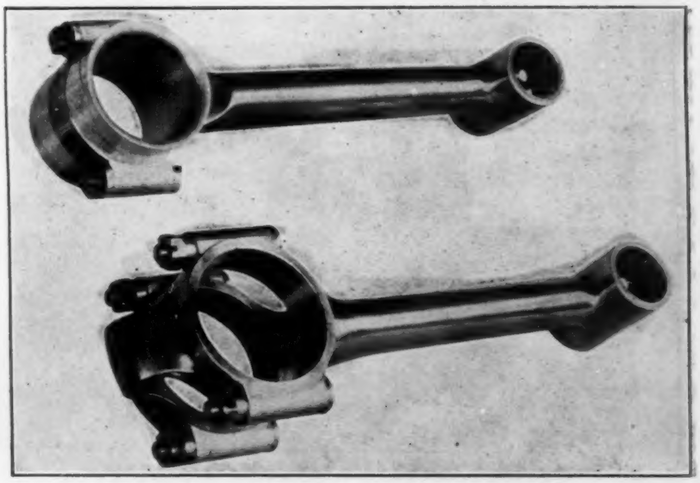

FIG. 6—CONNECTING-RODS USED ON THE MODEL A ENGINE

This Design Consisted of a Steel Forked-Rod Bearing on the Babbitt-Coated Shell of the Blade Rod That in Turn Was Babbitt Lined and Bore on the Crankpin

for a short portion at the top; the valves seat in aluminum-bronze rings; the spark-plugs are carried in aluminum-bronze bushings and the cylinder sleeves, spark-plug bushings and valve seats are all shrunk into place. A four-cylinder block of this construction was built and run. To check up our previous results, standard exhaust-valves, such as previously used, made of chromium steel and mushroom in shape, were first tested. These gave out in 48 hr. Next, several other materials were tried without success. Then we substituted mushroom-shaped silchrome valves for two standard exhaust-valves and chromium-steel tulip-shaped valves for two other exhaust-valves. These valves ran for 150 hr. with no drop in the power output, and we decided to stop the test and make a compromise valve for future duration running that consisted of silchrome material in the tulip shape.

This experiment showed that the original material could be used satisfactorily in a different shape, or the shape could be retained and the material changed. Fig. 5 illustrates the development of this exhaust-valve, the left-hand valve being an early type of tungsten steel, the central valve the intermediate type of chromium steel and the right-hand valve the latest type of silchrome steel with tulip-shaped head. The new cylinders cooled more efficiently, as was shown by the fact that it was possible to develop 130 lb. mean effective pressure on aviation gasoline without serious detonation. After the 310-hr. test, as noted above, no measurable difference in the tappet clearance could be found, showing that the valves were not pounding into their aluminum-bronze seats. Moreover, the power developed was slightly more than that at the start of the test. These cylinders reduced the weight of the engine, plus water, by 5 per cent.

Design of the Connecting-Rod

The connecting-rod design originally used consisted of a steel forked rod bearing on the babbitt-coated shell of the blade rod, which in turn was babbitt-lined and bore on the crankpin. This is shown in Fig. 6. The construction used in the later models is illustrated in Fig. 7. In the "marine" type, as this is called, the forked rod carries a babbitt-lined bronze box-bearing on the crankpin and the blade rod bears on it. The principal difficulty with the latter construction was caused by the flexing of the bronze shell, which in turn disintegrated the babbitt lining. To develop a better design, several experiments were tried, including the use of steel babbitted inside and outside instead of bronze shells, these being stiffer than the bronze; two types without babbitt also were tried, one of phosphorbronze and the other a copper-lead-tin alloy. The steel bearings functioned more satisfactorily than the bronze, which checked the theory that rigidity was lacking in the babbitt-lined bronze boxes. Neither of the unlined bearings gave any trouble from flexing but, as the copper-lead-tin alloy would operate without oil for short periods as well as the babbitt-lined bearings, this material was chosen for the final bearing. It seemed next to impossible to provide the requisite rigidity for a satisfactory babbitt-lined bearing without undue size and weight, so we removed the troublesome element, that is, the babbitt. These bearings were run 572 hr. at full power without adjustment, and no appreciable wear could be measured at the end of this time. These tests were conducted with an oil pressure of from 50 to 75 lb., using a standard lubricating oil such as is specified by the Navy. Fig. 8 shows a modification of the marine-type rod used in a large 12-cylinder engine, the T-3. It is interesting to note the rugged construction used.

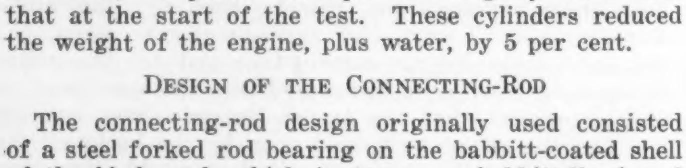

Fig. 7—The Connecting-Rod Design Used in the E-4 Engine
In This So-Called Marine Type the Forked Rod Carries a Babbitt-Lined Bronze Box-Bearing on the Crankpin and the Blade Rod Bears on It. The Principal Difficulty Experienced with This Construction Was Due to the Flexing of the Bronze Shell Which in Turn Disintegrated the Babbitt Lining

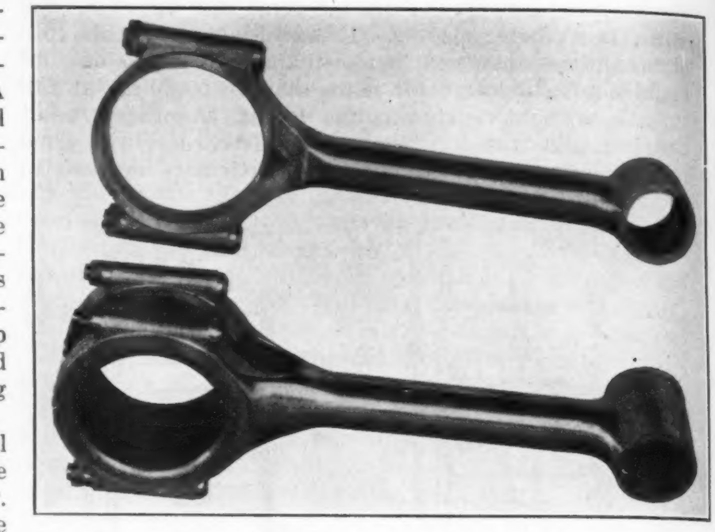

Fig. 8—Connecting-Rods Used on the T-3 12-Cylinder Engine
This Modification of the Marine Type Is Interesting Because of the Rather Rugged Construction Employed

We have always had considerable difficulty in obtaining satisfactory ignition equipment. The standard of workmanship for such apparatus was raised during the war, only to fall back again to a very low ebb during the last few years. A magneto manufacturer believed that no necessity for more than ordinarily good workmanship in his aviation product existed and commenced fabricating parts in the same department with other commercial electrical apparatus. To make matters worse, several ignition manufacturers decided that it was not worth their while to continue with aviation work. All this limited our supply of ignition equipment and caused considerable trouble. Fortunately, conditions are changing again for the better, and some of the accessory companies are looking farther ahead. Magnetos have been generally used on the recent 12-cylinder engines and, since the engine speeds are high, it is not unusual to find magnetos running from 3000 to 3600 r.p.m. This high speed has caused considerable trouble, but with high-speed breakers and better workmanship satisfactory equipment is now available. The same criticism as

that made with regard to magnetos applies to spark-plugs, namely, poor workmanship. Fairly good porcelain as well as mica plugs are available, but their average performance is not so good as the rest of the powerplant. The situation regarding carbureters is better, for the continued interest and the untiring cooperation of one of the large carbureter manufacturers have resulted in a progressive development that has kept pace with the progress of the engines themselves.

Defects Developed by Duration-Running

The duration-running of Liberty engines has developed certain other interesting defects. Lack of crankcase rigidity has caused broken camshaft-housings. The long and rather small diameter crankshaft, 2⅝ in., has resulted in timing-gear failures, due to torsional vibrations in the shaft. This condition, in connection with light webs and shafts of inferior material, has resulted in a number of broken shafts. A comparison of the Liberty crankshaft with one of later design is shown in Fig. 9. In spite of the fact that the latter shaft transmits 55 per cent more power and is considerably more rigid, its weight is only 17 per cent greater than the Liberty shaft. The deflection of the Liberty cylinder-heads has been shown to cause valve, spring and rocker-arm failures, loss of power due to the effect on the engine timing, and leaky cylinder water-jackets. The exhaust-valves of mushroom shape and tungsten steel are far from satisfactory, as leakage promptly results in burning a large hole in a valve. The connecting-rod bearings give trouble from the loss of babbitt due to their flexibility. Long-continued operation at high speeds and defective material have caused a number of connecting-rod failures. The storage of engines with steel cylinders and metal water-jackets has shown that, unless precautions are taken in their construction, no amount of slushing will prevent the jackets from rusting out after several years' idleness. This has made it necessary to replace numbers of Liberty-engine cylinders, besides causing several crashes and forced landings.

The Liberty engine was designed 8 years ago and for a long time has been one of the most reliable powerplants in existence. For that reason, its service performance should be considered in future design. This engine is an excellent example of the fact that any good engine

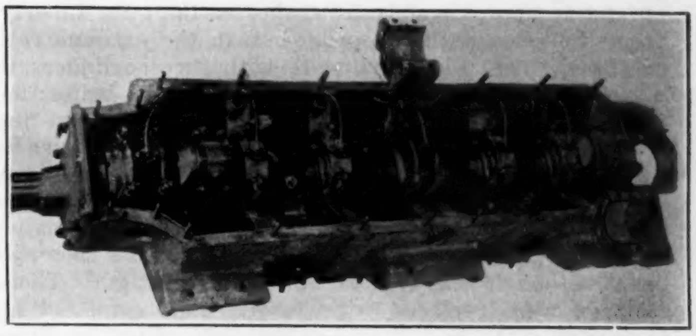

Fig. 10—The Crankcase of the Wright T-3 Engine
Note the Forged Aluminum Bearing Cap Construction Used in This Engine for the Center and Forward Main Bearings. This Arrangement Was Adopted After the Heat-Treated Cast Aluminum Caps Originally Installed Had Failed from Fatigue

is reliable at a certain output. As a matter of fact, a Liberty engine, operating at slightly less than normal speed and developing 350 hp. instead of 420 hp. has a comparatively long life. In this case, the weight is 2½ lb. per hp. Many engines are capable of much lower weights per horsepower for short periods, but no engine weighing less than 2 lb. per developed horsepower has been reported as yet to have passed a long duration-test successfully. When the power is increased much beyond the original design basis and an effort is made to hold to the higher power over long periods, engines are literally torn apart. Cylinder blocks begin to carry away from the main part of the crankcase, taking the top of the case with them. This trouble usually commences at the ends of the blocks, as the end cylinders have only one cylinder to help tie them to the case, whereas the central cylinders have at least one cylinder on each side. Cylinder-heads come off, crankshafts, rods and gears fail and so forth.

The Wright T-3 Engine

The development in the last 2 years of a 1947-cu. in. 60-deg. V-type 12-cylinder water-cooled engine, now known as the Wright T-3, brought forth a different set of interesting experiences. This engine was designed primarily for reliability and long life, but every effort was made to make it compact as well. The result was

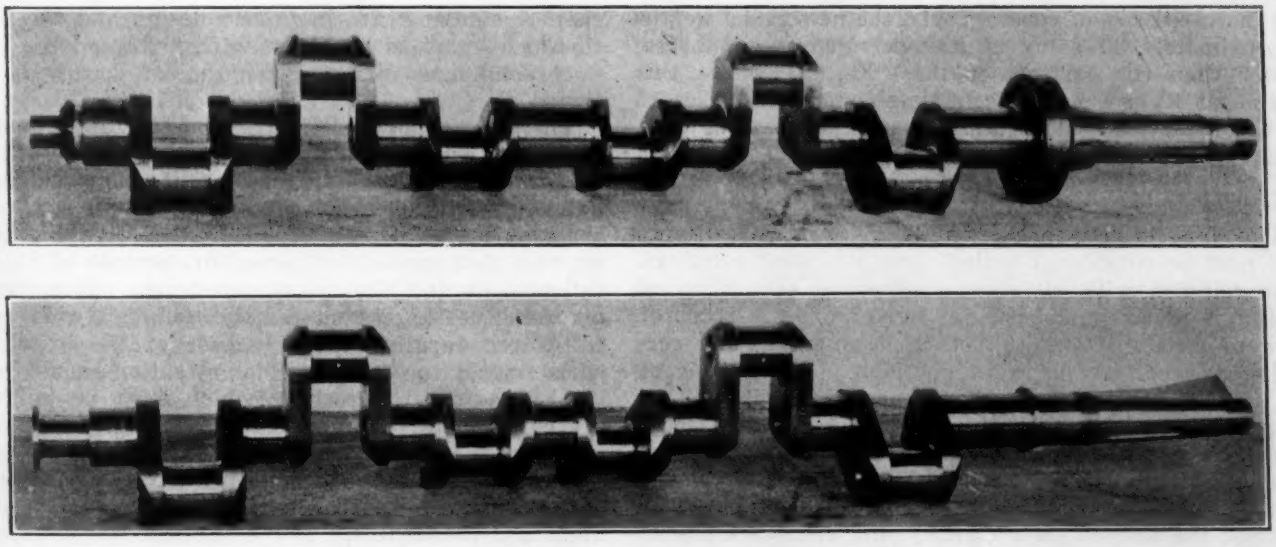

Fig. 9—A Comparison of Engine Crankshafts
The T-3 Crankshaft Shown Above Is 3.250 In. in Diameter and the Bearings for the Connecting-Rods Measure 3.000 In. in Diameter and Are 3.781 In. Long. The Corresponding Dimensions for the Liberty-Engine Crankshaft Shown Below Are 2.625 In., 2.375 In. and 2.000 In. Respectively

an engine approximately 5 in. shorter than the Liberty, from the rear of the propeller-hub to the extreme rear of the engine. Block cylinders with three cylinders in a block were used, each bank of two blocks being tied together with a cambox that is carried across the top of both. The crankshaft with 3-in. diameter journals was supported in the upper half of the crankcase, and cast-aluminum bearing-caps of generous proportions were used for the central and forward main-bearings. Duration running showed that this cast material, although heat-treated, failed from fatigue. These castings were replaced with forged aluminum and no further trouble has been experienced. Fig. 10 illustrates the forged bearing-cap construction. In a like manner forged aluminum rocker-arms were used to reduce the weight. Since they were subject to severe reversals of stress it was found that they were also unreliable. To make them sufficiently strong, it appeared that they must be approximately as heavy as the steel forgings that they were to supersede. The original engine was intended to develop 500 hp. at 1800 r.p.m. It was soon obvious, however, that there was a demand for a more powerful engine; consequently the power was raised to 650 hp. at 2000 r.p.m. for certain special work. Based on the success of these tests, a new model was developed with modifications designed to overcome certain defects that we felt sure would cause trouble in the original model in long-time operation at the higher power and speed. The crankshaft main-bearings were increased to $3\frac{1}{4}$ in. in diameter. To lighten the engine, the shaft was shortened approximately 1 in. in the center main-bearing, and the connecting-rods were shortened, which drew the cylinders in toward the crankshaft, making the crankcase shallower from the center of the shaft to the cylinder pads. However, to keep the same beam strength longitudinally, the new case is deeper from the center of the shaft to the parting line, while maintaining the same total depth as that of the original case. Bearing surfaces were increased in some cases, and certain parts were made stronger to guard against fatigue failures. This engine has been satisfactorily used at speeds greater than 2200 r.p.m., developing 750 hp. with a mean effective pressure of approximately 140 lb. It is exceptionally smooth in operation at all speeds, and none of the troubles that have previously been ascribed to lack of rigidity has been apparent. Despite the increased size of several parts, the new model weighs approximately 20 per cent less per guaranteed horsepower than the original engine. Fig. 11 shows this engine at its present state of development and Fig. 12 of the Liberty engine is included for purposes of comparison.

Application of Experience to Future Design

The application of this experience to future design will next be considered under certain general headings.

In common with all other engineering, the simplest design is always the best, not only from the point of view of reliability but of manufacturing cost and servicing as well. As mere weight is impossible, it is of the utmost importance to have correct distribution of proper material in each piece. Large bearing surfaces should be provided. These do not necessarily require correspondingly large weights. In considering the proper proportions for each part, it is important to bear in mind the necessity for rigidity, the average material available, the dimensional errors that are likely to occur in manufacturing, the effect of fatigue and the operating conditions under which the powerplant will be expected to function. As in electrical work, it is necessary to be sure that there is a "closed circuit" of forces in each assembly; for instance, the cylinder-heads must be tied to the crankshaft bearings. It often happens that such a condition is only partly taken care of.

A single material may be the most desirable for any particular part. As a rule, however, several are more or less equally usable, provided they are properly distributed, and the distribution may not be the same for any two. The use of improper material or improper heat-treatment invariably shows up on long runs. This class of trouble most often occurs in valves, valve-springs, valve-stems, gears, water-pump thrust-buttons, rocker-arms, rocker-arm rollers, piston-pins and the like.

Rigidity must be considered in every piece and in the assembly as a whole. For instance, most big-end connecting-rod-bearing failures are caused by the lack of rigidity. Combinations of parts in certain ways secure this feature without additional weight; for instance, block cylinders as compared with individual-cylinder construction. With higher speeds of operation, just as in motor-car work, it is absolutely necessary to have rigid crankshafts and crankcases.

Either reasonable factors of safety must be used or very fine material. The former method is recommended, as it is within the control of the engineer. The factors of safety in each part should not be based on the best material or on the most perfectly made part, but rather on the average material that will be used in production, allowance being made also for slight inaccuracies in machining. The use of the elastic-limit rather than the ultimate tensile-strength as a basis of calculation is recommended. Many otherwise excellent designs have been failures because insufficient consideration was given to the average material available. The computation of stresses and factors of safety must, of course, be based on more or less arbitrary assumptions as to the forces involved. For this reason, many engineers are inclined to underestimate the value of such calculations or to disregard them entirely. This appears to be a mistaken point of view, for it has been found that a rather complete stress-analysis of a new design will often reveal weak points that would otherwise have been discovered only at the cost of wrecking expensive engines. The comparative value of such calculations, that is, the comparing of the strength of a newly designed part with that of similar parts in proved design and the proportioning of various members so that those doing similar duty shall have similar strength, can hardly be questioned.

The proper consideration of the fatigue of materials is becoming more and more important in aircraft work, now that we are striving for long life and maximum reliability with high mean effective pressures. Often new types of engine will satisfactorily pass the standard 50-hr. test that consists of nine 5-hr. periods of $\frac{1}{2}$ hr. at full throttle and $4\frac{1}{2}$ hr. at nine-tenths full power, and one 5-hr. period at full throttle, but fail when put on full-power duration tests, because of the breaking of parts from fatigue. Particular attention should be paid to changes of cross-section, which must be gradual to prevent the localization of stress. For the same reason, generous fillets should be used everywhere. This is a truism that is often lost sight of. It has been our experience that the use of steel with a very high elastic-limit and consequently low elongation for crankshafts and rods tends to aggravate its breaking down in service on account of fatigue. This may be due to brittleness. The only final measure of the fatigue of a part is the

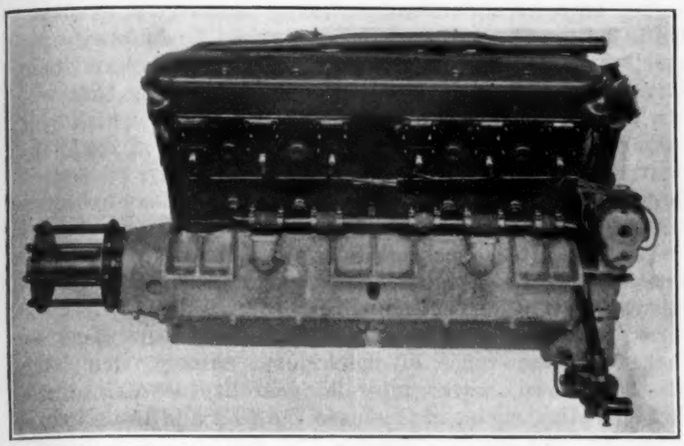

FIG. 11—EXTERIOR OF THE WRIGHT T-3 ENGINE
As Built at Present This Engine Has Been Run at Speeds in Excess of 2200 R.P.M. and Has Developed 750 Hp. at a Mean Effective Pressure of Approximately 140 Lb. per Sq. In. Despite the Increased Size of Some of the Parts, the New Engine Weighs Approximately 20 Per Cent Less per Guaranteed Horsepower than the Original Engine

actual operation of the part in an average-production engine, run at full power over long periods.

Aside from those due to fatigue, probably the greatest number of failures occurs from improper lubrication. Hardly ever do these failures occur in major parts, as these usually are properly oiled, but they frequently occur in pump or valve-operating mechanisms because of lack of forethought in design. Sometimes a part fails, not because of insufficient lubrication, but because of too small oil-passages, which gradually clog up. Insufficient strainer areas also cause trouble, as well as reduced bearing-clearances, on account of operating temperatures that result from continuous running. It is often difficult in the latter case to determine whether lack of lubrication or improper clearance has caused the failure.

Conditions existing for the storage of powerplants must be considered. It should be possible to protect the entire engine properly from rust, internally as well as externally.

Many unexpected failures occur because enough consideration has not been given to the operating conditions of the powerplant. We can expect only that each engine will have fuel, oil and water. Beyond this, there are a number of operating conditions that the designer hopes will be maintained, but he cannot go farther than hope. Wide variations of temperature are to be expected, as much as 90 deg. fahr. being not unusual in a single flight. In some ways it is hard to connect temperature with failures, but if insufficient heat is applied to the intake system, for instance, the cold air drawn through the carbureters will form ice on the throttles, gradually diminishing the engine power and making it impossible to close the throttles. Exposed oil-piping should be reduced to the minimum for this reason. Moreover, since airplanes as a rule are kept in cold hangars, consideration must be given to starting in winter weather. The actual starting, of course, has nothing to do with reliability, but the results of cold-weather starting are often detrimental to the life of the engine, particularly if the lubrication of various parts is inadequate during the initial running. Inexperienced pilots and mechanics can do much harm to any engine. This is a condition that must always be considered, and precautions must be taken, so far as possible, to avoid damage from operating with boiling water, or at speeds higher than normal, with little or no oil-pressure, and the like.

As higher speeds, larger power outputs and greater durability are required more and more, precise engineering will be necessary. This all means that new light-weight materials with better strength-to-weight ratios will continually be more in demand.

DEVELOPMENT OF DESIGN

The most interesting and important period in any design comes during the development testing. Many features thought to be desirable on the drafting-board are likely to be found wanting during the test. Considerable care must be exercised in making the proper deductions from the test results, as it is readily possible to make an erroneous decision that is based on inaccurate or incomplete information. Knowing the reason why a thing has happened is more than half the battle in remedying a defect.

Duration tests of new types of engine completely equipped and run under severe conditions so far as possible have afforded a thoroughly satisfactory means of developing reliable powerplants. These tests usually prove that the initial design, as a whole, is too light, which is only natural when it is considered that the engines are designed to weigh as little as possible per horsepower; consequently, the developed engine of each model usually weighs more than the original model. Poor accessibility for inspection and adjustment usually shows up on testing much more clearly than on the drafting-board.

Our usual method of developing a design, provided it includes a new type of cylinder construction, is first to construct a single cylinder and test it thoroughly, using the proposed piston as well as the entire cylinder and valve-operating mechanism. From this test it usually is possible to decide upon these items of design although, of course, other items, such as distribution and all parts connected with the crankcase assembly, have to be tested in a complete engine. The complete engine is usually given a 50-hr. test followed by a 300-hr. duration-run, after which the tests are conducted at higher compressions and speeds, for it seems desirable that any engine should stand from 10 to 15 per cent overload.

Fig. 13 shows the kind of apparatus usually used for performance and duration testing. It will be noted that the equipment is very extensive, including an electric dynamometer and a water brake with indicating load-scales, a heater to ensure uniform temperature of the air supply, a completely enclosed exhaust system, and the like. It may be of value to know that we have found it most desirable to plot the water and oil temperature-differences, as well as the fuel consumption and power,

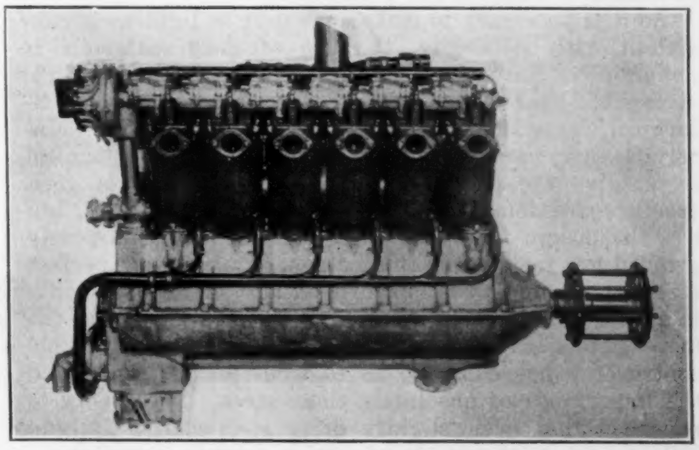

FIG. 12—THE LIBERTY AIRCRAFT ENGINE
This Engine Is Included for Purposes of Comparison

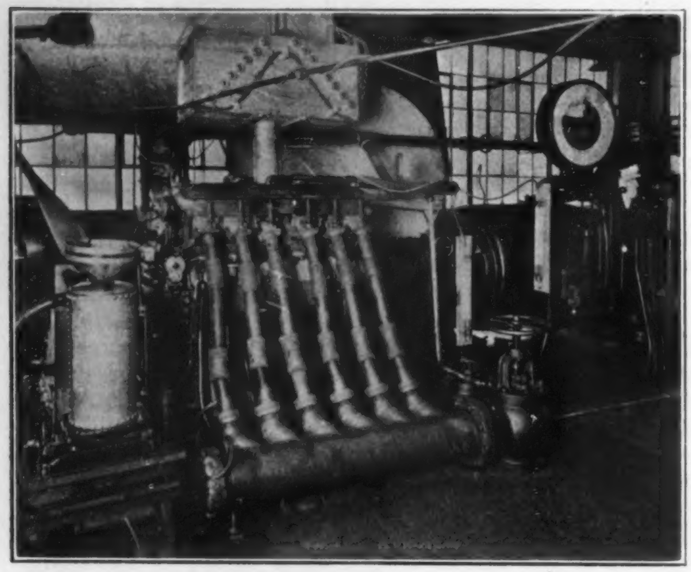

FIG. 13—EQUIPMENT GENERALLY USED FOR PERFORMANCE AND DURATION TESTING

Very Elaborate Apparatus Is Provided, Including an Electric Dynamometer and Water Brake with Indicating Load-Scales, an Electric Heater To Insure a Uniform Temperature of the Air Supply and a Completely Enclosed Exhaust System. As a Result of Using This Equipment It Has Been Found That Plotting the Oil and the Water Temperature-Differences as Well as the Fuel Consumption and the Power in the Duration Tests Will Serve, by the Change in These Values, To Give an Advance Warning of Trouble Even Before the Power Is Noticeably Affected

during the duration tests. The change in these values will almost invariably give advance warning of trouble, even before the power has been noticeably affected. For instance, gradually increasing temperature-differences and slowly rising fuel consumption usually indicate that the valves are beginning to leak. It has been found that it takes about a year to design, build and put an entirely new model through the preliminary tests. Another year is required to develop the production design thoroughly.

PRODUCTION OF DESIGN

After a new model has been thoroughly developed, the engineering work is by no means complete. The satisfactory and reliable powerplant is not the one that engineers build in an experimental shop, but the average engine turned out by the manufacturing department. It is very well to say that the experimental models function satisfactorily, but if the production models do not, the engine is unsuccessful. For this reason, the engineering department must follow closely both the manufacturing and the servicing, compromising the design where necessary to achieve the desired end.

As it is necessary to make each part as light as is consistent with reliability, the use of good materials is obligatory. Moreover, the materials must be of uniform strength. This makes it necessary to have close metallurgical inspection of all highly stressed parts. Materials that pass both the physical and the chemical tests, give the proper impact-value and show a good fracture are found entirely satisfactory in service, unless the design factors are too low. We have purposely avoided low factors for this reason, as absolutely perfect steel is hard to get even experimentally, and consequently is almost out of the question for production. With the more extended use of microphotographs, considerable controversy has come up as to what good steel is and the importance of absolutely clean steel. The theory is advanced that even slightly dirty steel causes fatigue failure. Since thousands of engines are in satisfactory operation with material in this condition, it is difficult to see why we should not continue to use it until something better is commercially available. Undoubtedly the steel mills can ultimately give us perfectly clean steel, but we must then develop methods of handling that will obviate its becoming dirty in forging, all of which will take time. It goes without saying that the aircraft industry will always welcome the opportunity to secure better materials. In the meantime, the designs must be laid out to use what is available.

The close tolerances used in aircraft engines require very careful dimensional inspection of every part entering each engine. The question is often asked, why such close limits are desirable. The answer is the same as that for every piece of machinery, namely, that long life is secured, better interchangeability is maintained and operating costs, in this case the fuel and the oil consumption, are lower. Besides the material and dimensional inspection, all engines are given long tests under their own power and are disassembled for inspection prior to the final acceptance test.

The actual shop practices differ in certain important respects from those of most automotive industries. To begin with, many parts are machined all over. It is particularly desirable that the surfaces should be smooth, as cracks often start from roughly machined surfaces. This means that heavy cuts cannot be taken, particularly in finishing. To obtain uniformity in strength, bolts and studs are made from heat-treated stock, rather than from annealed material that has been heat-treated after machining. This, of course, is an expensive method. Practically all highly stressed parts are heat-treated or seasoned after rough machining. The foundrywork is essentially difficult, as thin-walled castings are required and little allowance can be made for shifting cores and the like.

OPERATION OF DESIGN

Not only must each powerplant be properly installed, but it must be operated under certain fixed conditions of oil and water temperature, maximum engine-speed and minimum oil-pressure. The fuel and the oil used should meet the specifications recommended by the manufacturer. As in other automotive work, the engineer can hardly be expected to be responsible for the performance of his product unless it is run under the conditions and with the equipment recommended. The changing of carbureters, timing, spark-plugs and the like, causes just as much trouble in aircraft work as in motor-car service, and probably more. Even the best mechanism will not operate satisfactorily under adverse conditions. Most people would not think of operating a new car without proper oil-pressure, nor of running it at 70 m.p.h. as soon as it is delivered. Aviation engines are sometimes subjected to abuse of this kind, with the naturally disastrous results. The engine requirements for satisfactory service are few and simple. To secure long reliable service they must be complied with, regardless of the cost of the engine. A properly educated personnel makes frequent intelligent inspections and in this way takes care of the minor adjustments that are necessary in keeping mechanism in perfect condition.

It is usually difficult to introduce an entirely new model of engine, principally because the operating personnel is not familiar with it, and because suitable operating conditions have not been developed in the various airplanes in which it is to be used. The older and more widely known engines, such as the Liberty, for instance, now give very little trouble. When they

were first introduced, however, failures, which will be remembered by all those who handled the engines at that time, were numerous.

Conclusions

Reliability in light-weight aircraft engines is secured by the correct distribution of proper material and the adequate provision for the lubrication of the moving parts at all times. Each entirely new design becomes heavier as a result of duration testing, but by development through successive models the weight per horsepower can gradually be reduced to the minimum for an engine of given duration capacity. The thoroughly reliable powerplant is the result of a long and expensive process of evolution, both of design and of manufacturing methods. Production engines of proved design may be entirely unsatisfactory in service if insufficient care has been taken to see that the requirements of the design are complied with. The engineering department must, therefore, follow through the quality of the production work, as well as the troubles of the service department, if the product is ultimately to be successful.

Many of the lessons learned in obtaining aircraft engine reliability are directly applicable to motor-car work. Of course, in car design it is not desirable to carry many things to such extremes. On the other hand, the use of more rigid engine structures, larger-diameter crankshafts, better oiling, more extensive application of aluminum alloys and improved valve and valve-seat materials will result in a considerable saving in weight in the average motor car, as well as in increased durability and higher efficiency, as measured in miles per gallon.

STARTING POWER OF GASOLINE IMPROVED

SLIGHTLY better-starting qualities are possessed by the average present-day fuel gasoline than that tested in former winter surveys made by the Bureau of Mines. This conclusion as to the improvement in the starting power of the gasoline now on the market is deduced, as a result of the ninth semi-annual survey covering the gasoline sold in 10 American cities, from the slight decrease in the average for the 20-per cent distillation point and also in the average for the initial-boiling point of samples tested by the Bureau. Petroleum refiners in certain districts are, according to the results of the survey, obtaining a much better fractionation of the lighter products or in other words are, through greater skill and improved mechanical appliances, able to make cleaner cuts of gasoline and kerosene refined from crude oils, thus permitting an increased yield of gasoline without appreciably affecting the quality. About 2 years ago the 90-per cent distillation point in Federal specifications was raised to permit a greater quantity of gasoline to be obtained from a given quantity of crude oil, while still maintaining an internal-combustion engine fuel of satisfactory quality. When this change was made the end-point in the distillation was allowed to remain at the previous figure and a question arose as to whether refiners would be able to take advantage of the increase in the 90-per cent point and still maintain the old end-point. The results of the present survey indicate that this is being successfully done in certain districts. With the exception of these changes the winter grade of gasoline is not materially changed from that of recent years.

New York City, the City of Washington, Pittsburgh, Chicago, New Orleans, St. Louis, Denver, Salt Lake City, San Francisco and Bartlesville, Okla., were covered in the recent semi-annual survey. In all cities except St. Louis and Denver the average of all gasoline samples tested was well within the range of the Federal specifications, although 74 out of the 149 samples tested, or practically one-half, failed to meet the Government specifications for fuel gasoline in some particular. The samples obtained in the City of Washington registered the least number of failures to meet the specifications.

An appreciable decrease in the initial-boiling point for the averages of the January, 1924, survey as compared with those of the seventh semi-annual survey made in January, 1923, is noted, although the change is not so marked in the averages for New York City, Pittsburgh and Chicago. In the averages for the 90-per cent distillation points of New York City, Chicago, St. Louis, Denver and Salt Lake City, an interesting change has taken place. The amount of the change for the first-mentioned city showed that the average 90-per cent point has been increased by 22 deg. without increasing the average for the end-point by more than 7 deg. In Chicago the average for 90-per cent point has increased 12 deg. and at the same time the end-point average has actually been decreased by 1 deg. The average for the 90-per cent point in St. Louis has increased by 17 deg. while the average for the end-point has only been increased by 4 deg. On the other hand, Denver and Salt Lake City show an increase in the averages for the 90-per cent and the end-points of 22 and 16 deg. respectively.

GOOD WILL

THERE is nothing conceivable in the world or indeed outside of it that can be held good without qualification, except a good will. A man's will is good, not because the consequences from it are good, nor because it is able to attain the end it seeks; it is good in itself or because it so wills.

By a good will is not meant mere well-wishing; it consists in a resolute employment of all the means within one's reach, and its intrinsic value is in no way increased by success or lessened by failure.

I must act in such a way that at the same time I can will that my rule of conduct should become a universal law.—Immanuel Kant.

Comparison of Ideal and Commercial Carbureter-Characteristics

By C. S. Kegerreis[1]

Annual Meeting Paper *Illustrated with* Photographs and Charts

SINCE previous papers by the author on this subject have dealt with the engine mixture-requirements at some length and these requirements are available to the public, only general information is included in the first part of this paper to illustrate the ideal carbureter-mixture requirements when using a fully developed acceleration device. In the second part, computed data illustrate the car carburetion-requirements of various cars for level-road operation. The car-test data were procured from various sources and combined with research results obtained in the Engineering Experiment Station of Purdue University to delineate the factors desired. The results show the information regarding the advisability of using straight-line mixtures.

The third part constitutes the main section of the paper, and especial attention is called to it. Data are presented on commercial carbureters, the results of several devices are shown in detail, and a summary of the 23 carbureters tested is included for the general conclusions. The test results consist of information on the effect of pulsations, on metering characteristics, on frictional loss across carbureter bodies and on the effect of air temperatures on metering. Using the methods of computation by which the data in the second part of the paper were determined, the results are expressed in terms of ideal mileage per gallon of fuel for various cars that are assembled into four classes. Using the same methods, the carbureter results were computed to show the economy any one device would effect in car operation and, in the fourth part of the paper, 11 devices are thus compared with the ideal carbureter at various car speeds.

HERETOFORE the carburetion section of the Purdue University Engineering Experiment Station has confined its efforts entirely to engine-carburetion research. Reference is made to the paper by C. S. Kegerreis and G. A. Young, entitled "An Experimental Survey of Gasoline and Kerosene Carburetion."[2] Data have been compiled on the mixture-ratios necessary for the development of the maximum power and the maximum thermal efficiency, and a compromise has been suggested that will result in good performance. The temperatures required for sufficient vaporization of the fuel to obtain the proper distribution in the manifold have been outlined. This extensive research has provided sufficient data so that, if certain car-factors are known, the results can be applied directly in the determination of the car mixture-ratio requirements. The first part of the paper deals with the ideal characteristics.

An analysis of car performance brings to light three things:

(1) The engine must develop its maximum torque

(2) Maximum efficiency must be maintained whenever possible

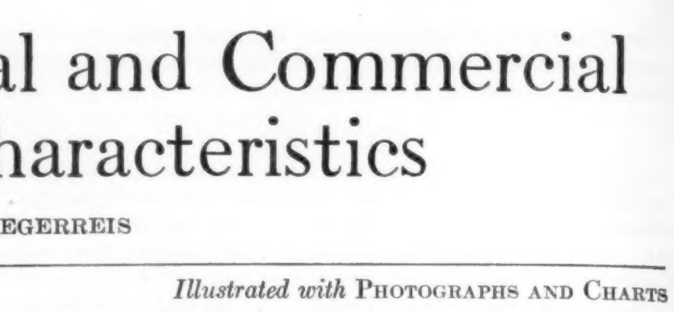

Fig. 1—Ideal Carbureter Requirements When Using a Proper Acceleration Device

The Chart Is Divided Into Four Different Curves Representing the Change of Engine Load, on a Flow-Rate Basis, at Constant Speed. It Presents the Ideal Mixture-Ratios That a Carbureter Must Deliver

(3) Proper acceleration must be provided when using economical mixtures

Properly included in the design of a carbureter, these three requirements will show the best performance coupled with the ultimate economy for any one car.

Presented in a graphical form, the ideal mixture-ratios that a carbureter must deliver are illustrated in Fig. 1. The chart is divided into four different curves representing the change of the engine load, on a flow-rate basis, at constant speed. In a medium-weight car of representative design, the curve *a b c* represents a car speed of about 7 m.p.h.; the others being approximately 18, 35 and 55 m.p.h. respectively. This set of curves covers a complete range of engine speeds and loads showing first, that the carbureter must recognize the engine load by varying the mixture-ratio in the proper manner and, second, that it must recognize engine speed by delivering constant mixture-ratios.

As the load is increased, the limits of inflammability are widened and the maximum efficiency is procured at succeeding leaner mixtures. Finally, a point is attained where an increase in the load, on a flow-rate basis, necessitates but a small change in the mixtures required for high efficiency. These points lie near the limits of lean inflammable mixtures and, if the accuracy of carbureter metering is considered, a constant mixture-ratio can be utilized effectively at all higher loads except that of full load. The demand at full load is the maximum torque; hence *c*, *f*, *i* and *m* represent high power, or a 24-per cent enrichment above the economical mixture.

One main point in presenting the data is that the leanest mixture used is 0.0625 lb. of gasoline per lb. of dry air. Previous reports have stressed 0.0700 lb. of gasoline per lb. of dry air as the leanest value used. From the engine's standpoint, when acceleration is provided primarily by the standard mixtures furnished, this richer value is necessary. This ratio allows, as stated previously, nearly maximum power and thermal efficiency as well as reasonable acceleration. For car

[1] M.S.A.E.—Research associate in the carburetion section, Purdue University Engineering Experiment Station, West Lafayette, Ind.

[2] See The Journal, January, 1923, p. 64.

requirements where the maximum power and the maximum thermal efficiency coupled with good acceleration constitute the desideratum, then, as stated, the leaner mixture-ratio becomes the ideal. It must be understood clearly that, in this case, a fully developed acceleration device is absolutely necessary. This device for changing car speed must deliver to the engine *cylinders* the mixture for high power instantaneously and temporarily. Engine speed does not affect the mixture-ratios; thus, points *a*, *d*, *g*, and *k* are required at zero load or idling. This brief résumé is presented to review a few facts on engine mixture-requirements before delving into the new data.

This paper makes no attempt to deal with manifolding problems. Our research has shown that proper vaporization can be attained such that crude manifolds can operate satisfactorily for constant-flow-rate conditions. In all cases throughout this presentation, proper manifolding is presupposed. To report data from the practical standpoint of fitting a carbureter to a manifold and the like would defeat absolutely any efforts to procure the results for ideal metering. The question of proper manifolding for acceleration is another problem, especially where wet mixtures are used that must be distributed satisfactorily at varying flow-rates. The acceleration factor in this work is presumed to take place in a dry-mixture state or its equivalent. Extremely wet, and cold, mixtures in most manifolds must be proportionately richer, which again is a consideration not necessary to discuss at present.

The distillation data since the work began about 4 years ago are given in Table 1. If the fuels are the same, then a direct comparison of engine and carbureter results can be made.

All of the fuel has been purchased from one company. The temperatures listed indicate that no great changes have taken place in this product during the period. Engine starting may be slightly more difficult now under cold operation. The end-point is lowered somewhat, as well as the intermediate points, but the volatility is not affected enough to show much difference in actual engine-operation.

Car Carburetion-Requirements

In discussing the car carburetion-requirements, only level-road operation will be considered. The other factors are evaluated readily from the engine requirements. The car data used are those published as the results of tests made by Prof. E. H. Lockwood, of Yale University, and A. L. Nelson, Chester S. Ricker and John C. Moore, all well-known automotive engineers.

Reference is made to the following papers: Rear-Wheel Dynamometer Tests[3], by Herbert Chase; the Fuel Problem in Relation to Engineering Viewpoint[4], by A. L. Nelson; and Valve Actions in Relation to Internal-Combustion-Engine Design,[5] by Chester S. Ricker and John C. Moore. Other car-test results were taken directly from Professor Lockwood's data.

These tests were made on brick, gravel and paper surfaces. The tests represent level-road conditions as closely as possible. The above surface being used for traction, the rolling resistance or road loss is somewhere near the minimum. This would indicate the use of a low percentage of engine load, or load factor, which would require the richer mixtures for level operation. The data used from these published tests consist of only

TABLE 1—DISTILLATION OF COMMERCIAL GASOLINE

Percentage Distilled Off	Temperature, Deg. Fahr.	
	First Fuel	Last Fuel
Initial Boiling Point	96	124
10	162	188
20	210	206
30	247	232
40	272	254
50	295	276
60	313	296
70	335	317
80	356	337
90	381	366
Maximum	425	398
Residue, per cent	......	2
Loss, per cent	......	1
Gravity, deg. Baumé	56.5	56.0
Average Number of Thermal Units per Pound, B.t.u. Low	18,900	18,900
Average Number of Thermal Units per Pound, B.t.u. High	20,300	20,300

the horsepower required for level-road operation and the maximum engine-power at various speeds. These data are necessary for determining the load factor under which the car is operating. This load factor at the various speeds was computed for each car, as shown in Fig. 2. The cars are designated by letters with an explanation of weight, gear ratio and wheel diameter. Car *A* is a light type with a maximum speed of 40 m.p.h. At the lower speeds, the load factor is high. At from 5 to 15 m.p.h., the load is nearly constant. At 5 m.p.h. and below this speed, the data are, in all cases, only approximations. In a few cases, 10-m.p.h. data are also approximations. The horsepower curves were prolonged to zero speed, resulting in the designated points above. Each car has its own combination of engine size, gear ratio, wheel diameter and car weight. Thus, at any speed, in Fig. 2, each car will have a definite engine load peculiar to itself. This being true, and knowing that the carbureter is required to compensate for the engine load, each car will have its own mixture-requirements.

The point can be illustrated by using the individual engine-loads for each car and combining these with other

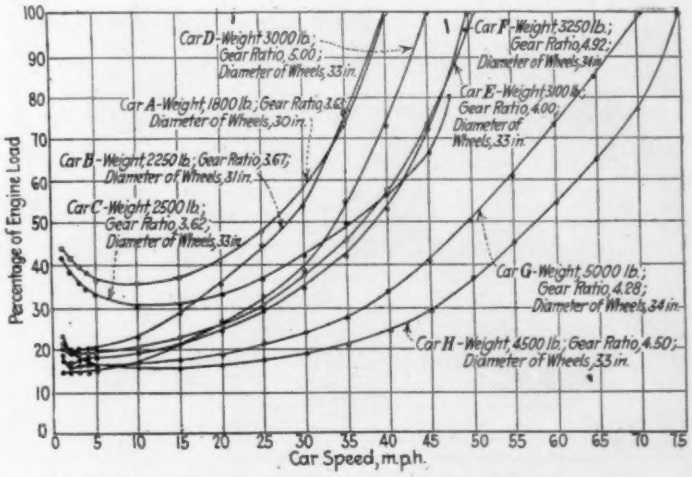

FIG. 2—LOAD FACTOR FOR EACH CAR AT VARIOUS CAR-SPEEDS

Data Obtained from Published Tests, Relating Only to the Horsepower Required for Level-Road Operation and to the Maximum Engine-Power at Various Speeds, Were Used for Determining the Load-Factor under Which the Car Is Operating. At Any Speed, Each Car Will Have a Definite Engine-Load Peculiar to Itself. Knowing the Load-Factor, the Required Mixture-Ratio Can Be Ascertained from the Data Presented in Fig. 1

[3] See *Automotive Industries*, April 20, 1922, p. 859.

[4] See THE JOURNAL, February, 1921, p. 101.

[5] See THE JOURNAL, September, 1922, p. 284.

average data derived from laboratory tests. Volumetric efficiency is the important factor from which the flow-rates of fuel and air can be computed, if the piston displacement, the load factor, the gear ratio and the wheel diameter are known. Having the load factor, the required mixture-ratio can be ascertained from the data presented in Fig. 1. The values for the volumetric efficiency were determined with respect to the load from several automobile engines, and the average result was used.

Choosing five of the cars and making the necessary computations for level-road operation, the mixture-ratios required at various car-speeds are plotted in Fig. 3. Car *D* requires nearly a straight-line ratio, a slight enrichment only is shown between 5 and 25 m.p.h. Idling with the car at rest is represented by a mixture of 0.082 lb. of fuel per lb. of dry air, a ratio of 12.2 to 1. At the maximum speed of the car, the mixture is enriched to the high power-value to insure full engine power. Whether or not this was obtained in the original tests cannot be stated. No doubt it was, as there is a 75 per cent mixture-variation before the power is affected appreciably. The load data are used *"as is,"* and the requirements are computed therefrom, which will suffice for the purpose in view. Car *W* presents an entirely different shape of curve at the lower speeds. An inspection of the others shows the detail variations. While cars *D*, *W* and *B* require the leanest mixture at 25 m.p.h., car *P* necessitates a speed of 50 m.p.h. before the load is sufficient to warrant using the lean mixture.

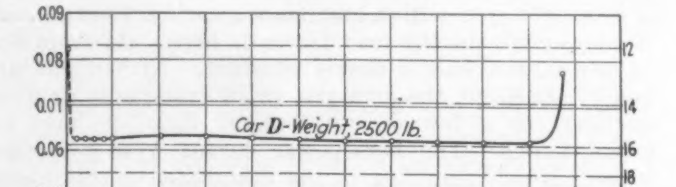

FIG. 3—MIXTURE-RATIO REQUIREMENTS AT VARIOUS CAR-SPEEDS

Five of the Cars Were Chosen, and the Necessary Computations Were Made for Level-Road Operation. The Load-Data Are Used "As Is," and the Requirements Are Computed Therefrom

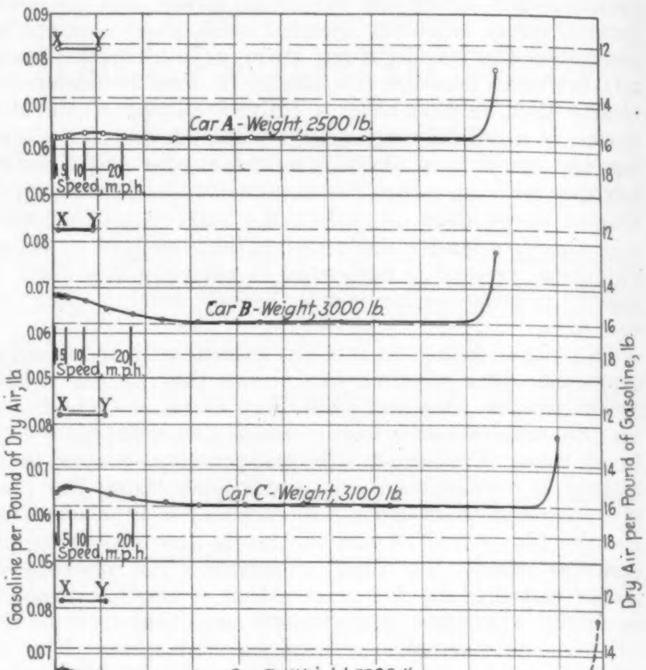

FIG. 4—MIXTURE-RATIO REQUIREMENTS ON AN AIR FLOW-RATE BASIS

Carbureter Performance in Terms of Mixture-Ratio and Flow-Rates Cause the Data To Assume a Somewhat Different but a Very Desirable Aspect for Engineering Purposes. One Car May Demand the Lean Mixture-Ratio at a 15-Cu. Ft. per Min. Flow-Rate; Another, at 25 to 30 or Even as High as 70 Cu. Ft. per Min. If the Low-Speed Values Are Accurate, Car Speeds Below 5 M.P.H. Often Demand Leaner Mixtures Than the Immediately Higher Speeds

Nearly every engineer desires that carbureter performance be expressed in terms of mixture-ratio and flow-rates; hence, the data are so converted in Fig. 4. Immediately it is found that the data assume a somewhat different aspect. One car may demand the lean mixture-ratio at a 15-cu. ft. per min. flow-rate, another at 25 to 30 or even as high as 70 cu. ft. per min. An interesting point, if the low-speed values are accurate, is that car speeds below 5 m.p.h. demand, in many cases, leaner mixtures than the immediately higher speeds. The usual practice is to provide much richer mixtures at the low flow-rates.

While discussing the low flow-rates, it is advisable to mention the idling with the car at rest. Curve *XY* represents the mixtures and the flow-rates computed for the point *X* as 150 r.p.m., and for the point *Y* as 1000 r.p.m. From our engine requirements, this mixture-ratio value must be 0.0820 lb. of gasoline per lb. of dry air. Idling at a normal speed with the car at rest then requires more air than car-speeds, on a level road, of 3 or 4 m.p.h. Many engines idle at higher speeds than 150 r.p.m., therefore, the condition is more aggravated

when working out the metering characteristics entirely on a flow-rate basis. The air consumption is in many cases too high at idling speed to supply the designated lean mixtures for level-road operation. Thus, either idling or economy at low level-road speeds will be sacrificed, provided the richer mixture at all idling conditions, although correct, is not absolutely necessary to fulfil them, especially if the level-road flow-rates are again provided at 10 m.p.h., or approximately 10 cu. ft. per min.

The flow-rates, as computed for the various cars, show that a flow-rate of 120 cu. ft. per min. usually suffices for the average size of car using a 1¼-in. carbureter. For the smaller cars using a 1-in. carbureter, we find that about 95 cu. ft. per min. is adequate. Cars of the type of car *E* require a much higher flow-rate; the value at 75 m.p.h. is computed to be about 200 cu. ft. per min.

Averaging the computed requirements for cars in the class of the Chevrolet, the Star, the Ford and the Gray, or those that can use a 1-in. carbureter or smaller, the lower curve *A* in Fig. 5 is representative. For the smaller cars in the class using the 1¼-in. size of carbureter, such as the Buick, the Willys-Knight and the Nash, the class average is shown by curve *B* in Fig. 5.

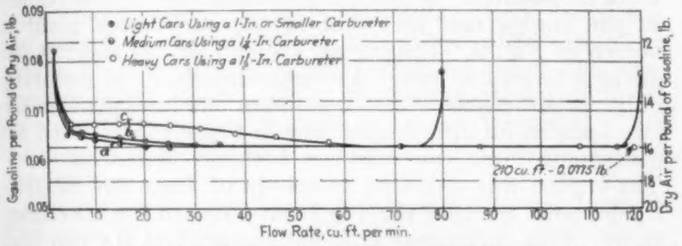

FIG. 5—AVERAGE LEVEL-ROAD MIXTURE-REQUIREMENTS FOR VARIOUS TYPES OF CAR

Curve *A* Averages the Computed Requirements for Cars That Can Use a 1-In. Carbureter or Smaller. Curve *B* Refers to the Smaller Cars in the Class Using the 1¼-In. Model. Curve *C* Illustrates the Difference Between the Average of the 1½-In. Class of Carbureter and That of the Smaller Ones. It Is Found That Each Class Has Its Own Requirements. The Three Different Classes Cannot Be Designed To Furnish the Same Mixtures at the Same Flow-Rates. The Large Carbureter Cannot Be Proportioned from the Smaller Design

Averages of four or five cars in this class present the same shape of curve as curve *A*, but richer ratios are required at the lower flow-rates. Curve *C* is plotted to illustrate the difference between the average of the 1½-in. class of carbureter and that of the smaller ones. From the few examples presented, we deduce that each class has its own requirements. When inspecting the curves for each individual car, it is found that each has its own requirements. In general, however, the variation is small enough so that the class average can well be used. Judging from the data presented, the maximum difference between the requirements of a 1½-in. and a 1-in. size of carbureter is only about 7 per cent. The small carbureter should not deliver so rich a mixture as the 1½-in. size at flow-rates of from 15 to 40 cu. ft. per min. or, as a result, the 7-per cent economy will be sacrificed. The large carbureter cannot be made leaner, because a 7-per cent change would cause the engine to backfire. Hence, the three different classes or models cannot be designed to furnish the same mixtures at the same flow-rates. Stating the situation in another manner, the large carbureter cannot be proportioned from the smaller design.

COMMERCIAL-CARBURETER TESTS

Much time is required to make an extensive test of a carburetion device on the dynamometer. The control of the various units of the apparatus and the recording

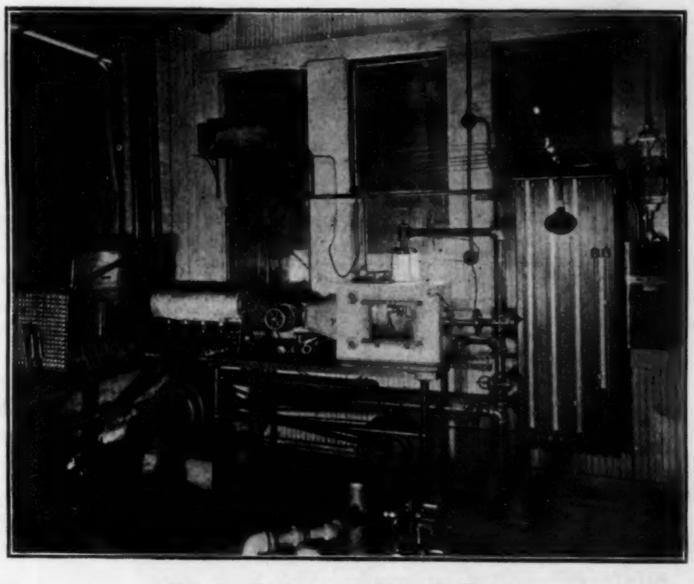

FIG. 6—CARBURETER TESTING-PLANT

Apparatus Designed and Built To Afford a Means of Making Extensive Tests of Carburetion Devices on the Dynamometer and of the Degree of Atomization Attained by the Different Carbureter Models Tested

of a large amount of data requires time as well as several test operators. It is desirable to show the atomization of all carbureter models in which atomization cannot be accomplished nicely on an engine. To fulfil these needs, the apparatus shown in Fig. 6 was designed and built. Fig. 7 shows a close-up view of the air chamber. Many are familiar with the equipment as it has been described in some publications, and details will, in the main, be dispensed with. Suffice it to say that the air is induced through the carbureter by an electrically driven vacuum-pump. The control of the intake of the pump is such that the pressure-flow relation is comparable to that in an automobile-engine manifold. The fluids used are measured by flowmeters that eliminate a great volume of computation. Readings can be taken accurately and quickly; in fact, when two men are operating the plant, 50 accurate tests per hour can be made.

The tests were conducted in such a manner that the effects of engine speed and load could be ascertained. In many cases a carbureter may be practically perfect

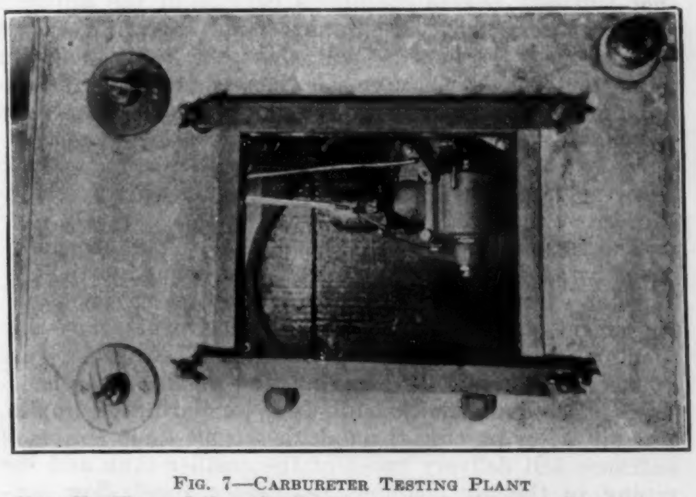

FIG. 7—CARBURETER TESTING PLANT

Close-Up View of the Air Chamber. Air Is Induced Through the Carbureter by an Electrically Driven Vacuum-Pump. The Pressure-Flow Relation Is Comparable to That in an Automobile-Engine Manifold Because of the Control of the Intake of the Pump. The Fluids Used Are Measured by Flowmeters That Eliminate a Great Amount of Computation and Readings Can Be Taken Accurately and Quickly

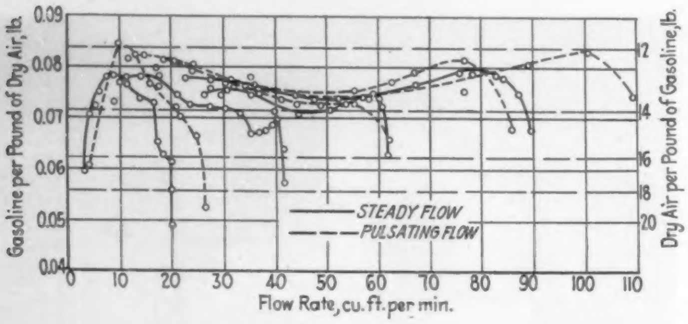

FIG. 8—COMPARISON OF CARBURETER METERING WITH STEADY AND WITH PULSATING AIR-FLOW; TEST-PLANT CONDITIONS

To Eliminate Pulsation, Air Tanks Were Added between the Vacuum Pump and the Carbureter *LMZ*, Reducing the Maximum Flow-Rate Somewhat, but the General Character of the Curves at the Various Speeds Is the Same

for speed but will not compensate for load. If it does not give the required load-characteristics, then a fuel loss of 24 per cent will be apparent. This loss is due to the fact that, without load compensation, the economical mixtures cannot be used. The tests were devised so that at least four individual speeds were run. At these constant speeds, the flow-rate was varied from no load to full load. Some flow-rate points will in this manner be run two or three times.

METHOD OF DETERMINING FLOW-RATES

A brief explanation of the method of determining the flow-rates at various engine loads is desirable. From engine tests at medium speeds, the ratio of airflow at zero brake-load to that at full load is 1 to 4. Making this determination on several powerplants from a single-cylinder to four and six-cylinder engines of various types, the average ratio was found to be that given above. At the lower and especially at the higher speeds, the ratio was found to change and vary somewhat from the value given. For this work, however, the given ratio was held as standard and is so applied in the tests.

PULSATIONS

Many expressions of opinion have been that pulsating flow may cause an error in the metering of a carbureter. The exact effect of pulsations on metering is as yet unknown. At intervals, a few data are brought to light. Much has been said about the carbureter testing-plant not fulfilling engine conditions because of the different types of pulsation. Preliminary tests have proved that the ordinary carbureter will show the same shape of metering-characteristic curve when running on the engine or on the testing plant. At the time the data were taken, no method of measuring the pulsations was available, but a few tests are presented which may aid in showing how nearly the test plant fulfils engine conditions.

The testing plant was changed to eliminate the pulsations by adding air tanks between the pump and the carbureter. Two tanks were added, the first having a displacement of 50 times the pump displacement per revolution and the second a ratio of 30 to 1. These tanks were connected in series by piping. The small-tank connections had to be made through 1-in. standard pipe nipples. The air, after passing through the larger tank, the small entrance and delivery tubes of the smaller tank and the piping to the air chamber represents steady-flow conditions as nearly as could be determined. Considering the volume displaced per pulsation to the volume of the tanks, with the above conditions, a ratio of 1 to 320 ought to prove ample.

The tests were made with three different carbureters, *LMZ*, *OSZ* and *XZZ*. The data on test-plant conditions, with and without pulsations, are shown in Fig. 8. With the tanks in place, the maximum flow-rate was reduced somewhat. The shape of the curves illustrates the story. The general character of the curves at the various speeds is the same. At some of the flow-rates, the values of the mixtures are identical. At the lower flow-rates, the load or the throttle position causes some discrepancies. The higher flow-rates are more nearly at the same throttle-position and show little or no difference in metering. Wide-open throttle causes very little change between steady and pulsating flow.

As carbureter *LMZ* was a non-air-bleed multiple-jet plain-tube device, it was decided to use an air-fuel-proportioning type, carbureter *OSZ*. In this case a change in the position of the air valve caused a change in the position of the fuel-metering pin. To delve more deeply into the problem, data were taken from the tests made with and without pulsations and, in addition, the carbureter was placed in a box and attached to a four-cylinder engine. The tests were made using the same flowmeters for air and fuel as before. Test conditions were made as nearly identical with the carbureter-plant tests as possible. A graphical comparison of the results of the engine test and that of the carbureter plant is shown in Fig. 9. The curves are similar throughout the various flow-rates run. A slight difference, in metering only, is noticeable. The maximum change between the two tests at an appreciable flow is 6 per cent. With engine pulsations, the mixture becomes somewhat lean. The engine was operated at speeds of from 600 to 1000 r.p.m., with the load varying from a low to the maximum value. This carbureter does not compensate for full load by providing richer mixtures at wide-open-throttle positions. Thus, pulsations as shown by the tests do not affect the metering when using a wide-open throttle. The same engine test is plotted for comparison with the regular carbureter-plant run with pulsations, in Fig. 10. In this chart the difference between the two tests is so little that no attempt will be made to differentiate the results.

The third type of carbureter used was a plain tube.

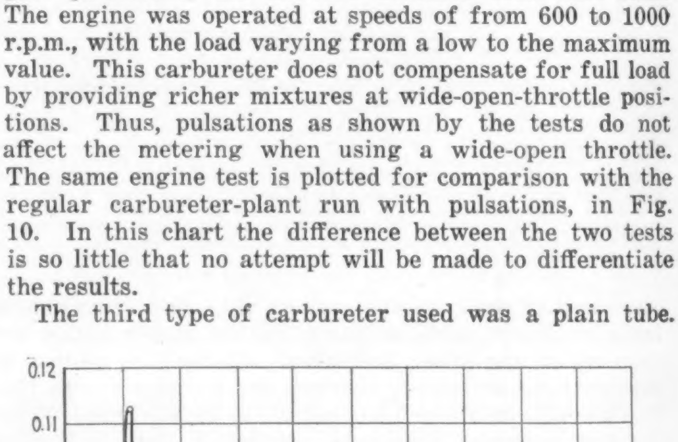

FIG. 9—COMPARISON OF ENGINE-TEST AND CARBURETER-PLANT-TEST RESULTS AT STEADY FLOW

Data Were Taken from the Tests Made with and without Pulsation. In Addition, Carbureter *OSZ* Was Placed in a Box and Attached to a Four-Cylinder Engine. These Test Conditions Were Made as Nearly Identical to the Carbureter-Plant Tests as Possible. The Curves Are Similar throughout the Various Flow-Rates. A Slight Difference, in Metering Only, Is Noticeable

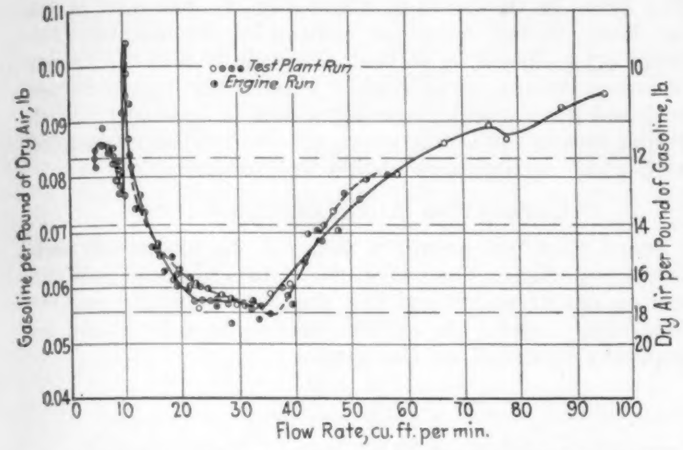

FIG. 10—COMPARISON OF ENGINE-TEST AND CARBURETER-PLANT-TEST RESULTS AT PULSATING FLOW, USING CARBURETER *OSZ*

With Engine Pulsation, the Mixture Becomes Somewhat Lean. The Engine Was Operated at Speeds Varying from 600 to 1000 R.P.M.

Air-bleeding was effected at a certain flow-rate. Making tests on the engine and with pulsations on the carbureter plant, the results obtained are shown in Fig. 11. The same characteristic curve is obtained in both cases, but the actual values of the mixtures are different. The engine tests show the leaner mixtures when the carbureter is throttled. Six of the points shown by black dots are at wide-open throttle in the engine tests. This carbureter does not result in identical mixtures in the two cases.

The results are meager, but they lead the way to show that each carbureter is a problem in itself when pulsations are concerned. Pulsations on an air-valve type might have been thought to have more effect than on a plain tube. Also, air-bleeding of the main jet may or may not affect the metering under a pulsating flow. No definite statement can be made as to the general effect on metering. One factor is proved, however, that the characteristic curve taken from this carbureter test-plant will check with the curve taken from an engine test. If this point is accepted, the tests made on the plant are correct for the purpose in view. Other superficial tests, together with the results presented here, lead one to believe that in many cases the metering as to mixture value is correct. Further research will clear this point conclusively.

CARBURETER METERING

Presenting data on commercial models and including a discussion of results and criticisms that may be both adverse and constructive is a rather delicate subject. Our efforts are intended to give aid in all cases, therefore code names will be used to represent the devices. In this manner, each company can obtain the results of tests on its own device and, in addition, compare the performance of the device with that of other similar models representative of the industry. All the carbureters were given the best adjustment possible. In every case where the results are applied to actual engine operation, the mixtures are vaporized sufficiently to allow proper distribution. Acceleration was determined only in a comparative way and cannot be reported here.

As the metering characteristics of the various devices are observed, the mixtures provided may be those of improper value for ideal engine-operation. It is merely a matter of percentage variation of which we make use in the comparison of the results. For this presentation, the various types of carbureter are divided into three classes, and will be grouped in that manner for discussion; (*a*) plain tube, (*b*) air valve and (*c*) constant vacuum and air-fuel proportioning. A large number of graphs are used to present the data.

PLAIN-TUBE CARBURETERS

The metering results of the plain-tube carbureters are grouped in Fig. 12. Carbureter *CCZ*, at the upper left, is somewhat representative of the usual type, being richer at idling and then tending to assume a constant mixture at higher flow-rates. The rich mixtures at the low flow-rates are too prolonged for, if much driving is done at about 15 m.p.h., a 17-per cent fuel-loss will be experienced. It is admitted that mixtures of this richness are fine for acceleration, but rather compromising for economy. The manner in which the air-bleeding is effected evidently causes some erratic metering. Wide-open-throttle operation at low speed may be somewhat impaired, as illustrated by *a* at 21 cu. ft. per min. At the extremely high flow-rates, a tendency toward enrichment for wide-open throttle is noticed, but it does not attain the required 24 per cent. The curves show four open-throttle points, but the enrichment is not provided for in any case. The carbureter for level-road operation probably above 35 m.p.h. is the ideal, as can be seen on comparing the ideal curves shown in Fig. 1.

Carbureter *PSA*, at the top center of Fig. 12, has the same tendency to start lean at idling, with a resulting enrichment and leaning as the flow-rate is increased. At a level-road speed computed to be from 15 to 25 m.p.h., the carbureter can be adjusted for economical operation provided the acceleration well is designed properly. Above these speeds, the mixture enriches rather rapidly. A larger venturi would lean the mixture at the higher flows or, if this were not desired, the main jet being air-bled, a change of air-bleeding could be effected. With proper detail changes, most plain tubes can be made to approach closely to the ideal conditions at the higher flow-rates. All these tests can do is to present the results of the device as found.

Carbureter *HKF*, at the upper right in Fig. 12, must be classed as a plain tube, although in some respects its design might suggest another type; the data shown immediately suggest poor idling. For a small car, it is necessary to provide proper mixtures at less than 7 cu.

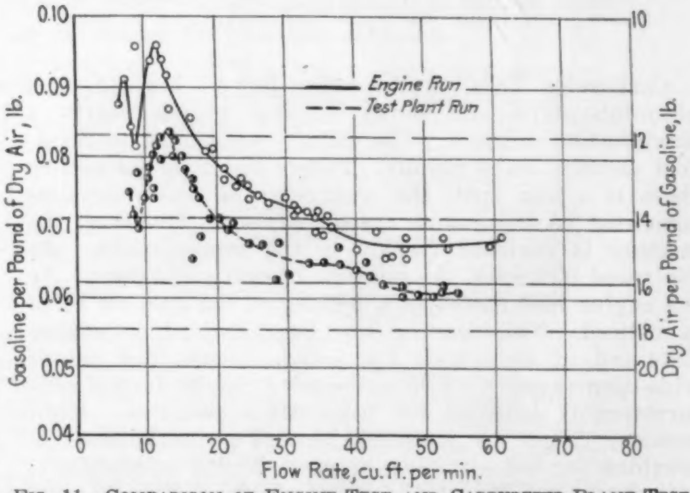

FIG. 11—COMPARISON OF ENGINE-TEST AND CARBURETER-PLANT-TEST RESULTS USING A PLAIN-TUBE CARBURETER *XZZ*

Air-Bleeding Was Effected at a Certain Flow-Rate. Tests Were Made on the Engine and with Pulsation on the Carbureter Plant. The Same Characteristic Curve Is Obtained in Both Cases, but the Actual Values of the Mixtures Are Different. The Engine Tests Show the Leaner Mixtures when the Carbureter Is Throttled

ft. per min. The idling was non-adjustable; hence, the metering could not be changed at the low flow-rates without affecting the higher. When used on a certain car as standard equipment, it has been found that trouble is experienced at speeds below about 8 to 10 m.p.h. The mixture curve aids in illustrating this point. As the car speed increases, on a flow-rate basis, the mixture increases in richness at such a rate that if the adjustment were ideal at 5 m.p.h., 30 per cent of the fuel would be lost at 30 m.p.h. At the maximum speed of the car, more than 50 per cent of the gasoline used is wasted. The metering is accurate as the various check points show. Continual adjustment must be made while driving, else little economy can be effected.

The hump in the curve at about 8 cu. ft. per min. is due no doubt to the main jet cutting-in, immediately followed by air-bleeding to keep the ratio within the proper bounds. At the three higher speeds, the mixtures are enriched prematurely, causing a loss in economy. With proper means for acceleration, excellent economy coupled with good performance should be obtained.

Compensated Auxiliary Air-Valves

Space does not permit a detailed discussion of each device reported. Therefore, the data are shown on the various charts and, from the discussions of the several plain-tube models, the salient virtues or defects can be inspected in detail on the graphs.

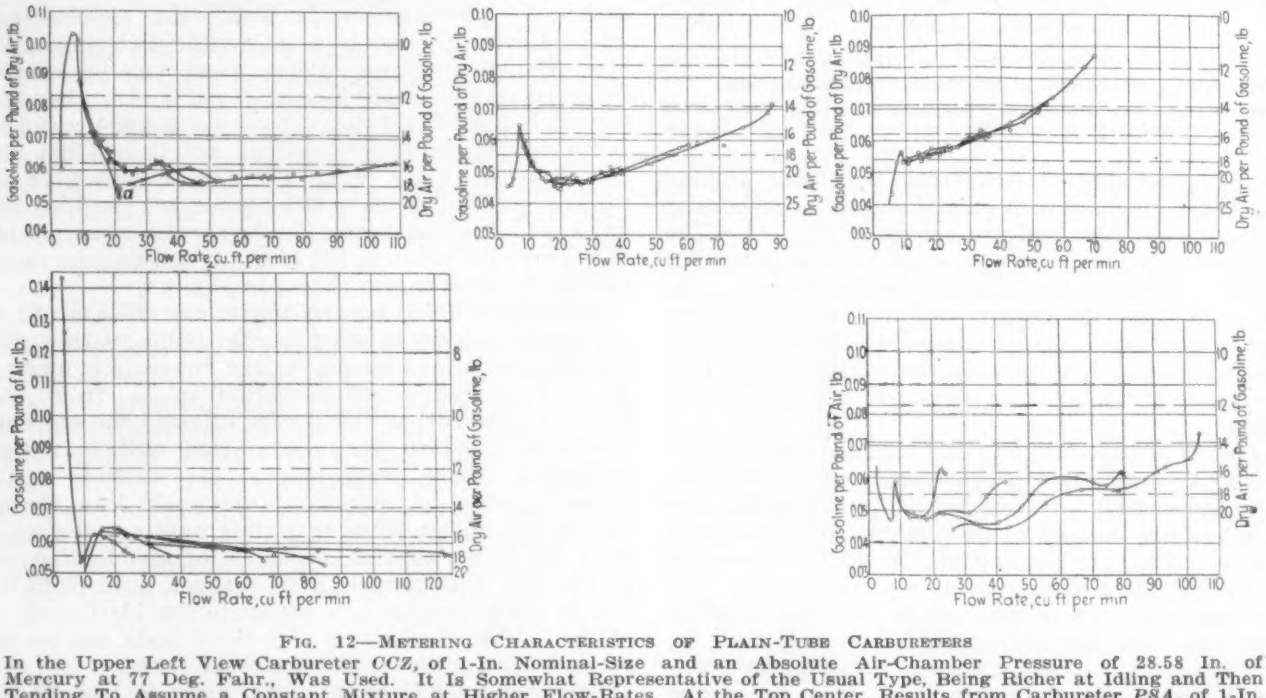

FIG. 12—METERING CHARACTERISTICS OF PLAIN-TUBE CARBURETERS

In the Upper Left View Carbureter *CCZ*, of 1-In. Nominal-Size and an Absolute Air-Chamber Pressure of 28.58 In. of Mercury at 77 Deg. Fahr., Was Used. It Is Somewhat Representative of the Usual Type, Being Richer at Idling and Then Tending To Assume a Constant Mixture at Higher Flow-Rates. At the Top Center, Results from Carbureter *PSA*, of 1-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.62 In. of Mercury at 66 Deg. Fahr., Are Shown. It Has the Same Tendency To Start Lean at Idling, with a Resulting Enrichment and Leaning as the Flow-Rate Is Increased. Carbureter *HKF*, of 15/16-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 29.13 In. of Mercury at 59 Deg. Fahr., Gave the Results Shown in the Upper Right View, Which Suggest Poor Idling. It Is Classed as a Plain-Tube Type, Although Its Design Suggests Another Type. In the Lower Left View, Carbureter *TSM*, of 1¼-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.90 In. of Mercury at 58 Deg. Fahr., Shows Nearly a Straight-Line Mixture. The Idling, Being Open to the Manifold Vacuum, Leans Rapidly. Before the Main Jet Cuts-In There Is a Lean Spot, but the Mixture Is Enriched Quickly to the Proper Value. Many Features of the Ideal Design Are Exhibited by the Results from Carbureter *SSO*, of 1-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.53 In. of Mercury at 73 Deg. Fahr., Shown in the Lower Right View. The Idling Shows the Desired Leaning of Mixture at Low Speeds; Then, as the Load Is Increased, the Ratios Are Somewhat Constant Until, Finally, an Enrichment is Effected at Wide-Open Throttle

Carbureter *TSM*, at the lower left of Fig. 12, is a plain-tube type and shows at first glance nearly a straight-line mixture. The idling, being open to manifold vacuum, leans rapidly. Before the main jet cuts-in there is a lean spot, the occurrence of which depends somewhat on the engine speed and load. However, the mixture is enriched quickly to the proper value. As the speed increases, the mixture is nearly constant. As the engine load increases a leaning of the fuel-air ratio is noticed. This leaning has been noticed on engine tests and, at moderately low speeds, occurs long before wide-open throttle. This carbureter results in fine performance if adjusted for high power-mixtures. High economy cannot be procured, because no enrichment is provided for hill climbing or open-throttle operation.

Carbureter *SSO*, at the lower right of Fig. 12, has many features of the ideal design. The idling shows the desired leaning at low speeds; then, as the load is increased, the ratios are somewhat constant until, finally, an enrichment is effected at wide-open throttle.

Judging from general appearances only, carbureter *KMB*, shown in the upper left corner of Fig. 13, is similar to the ideal. A small lean spot is noticeable at a low flow-rate. Some of the higher flow-rates show an inaccuracy in metering, as is perceived in a small degree at the ordinary rates.

When the data on carbureter *ABB* are inspected, rather poor idling is no doubt present if economy is desired at any of the higher speeds, as indicated in the upper central view of Fig. 13. Obviously, poor hill-climbing and poor economy are noticed with the actual car.

Carbureter *GJZ*, shown in the upper right corner of Fig. 13, has nearly the characteristics for level-road operation, but the economical mixtures are not obtained at the lower flow-rates. Of course, hill-climbing ability is sacrificed. The metering at ordinary speeds is somewhat erratic.

A certain car when using carbureter *UTR* would not idle properly and give fair economy also. The data,

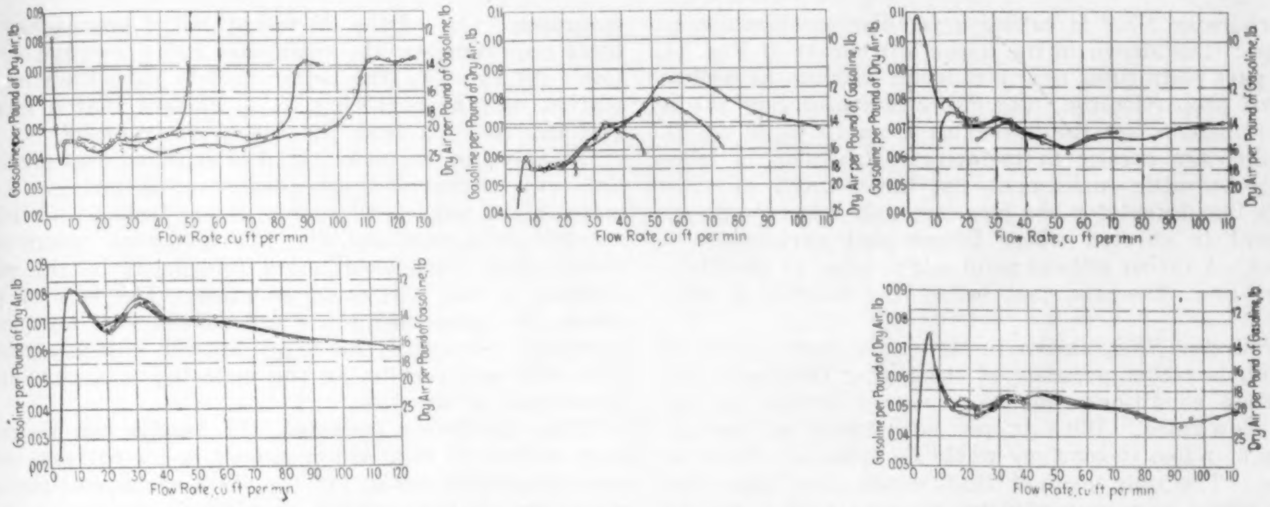

FIG. 13—METERING CHARACTERISTICS OF COMPENSATED AUXILIARY-AIR-VALVE CARBURETERS

Using Carbureter *KMB*, of 1½-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.30 In. of Mercury at 72 Deg. Fahr., a Small Lean Spot Is Noticeable at a Low Flow-Rate and Some of the Higher Flow-Rates Show Inaccuracy in Metering, as Indicated in the Upper Left Corner. For Carbureter *ABB* in the Upper Central View, of 1¼-In. Nominal- Size and an Air-Chamber Absolute-Pressure of 28.37 In. of Mercury at 53 Deg. Fahr., Rather Poor Idling Is Doubtless Present if Economy Is Desired at Any of the Higher Speeds. Carbureter *GJZ* Has Nearly the Characteristics for Level-Road Operation. It Is of 1-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.64 In. of Mercury at 70 Deg. Fahr. The Results in the Upper Right Corner Show That the Economical Mixtures Are Not Obtained at the Lower Flow-Rates, Hill-Climbing Ability Is Sacrificed and the Metering at Ordinary Speeds Is Somewhat Erratic. The Lower Left Corner Shows Data for Carbureter *UTR* of 1¼-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.62 In. of Mercury at 67 Deg. Fahr. It Would Not Idle Properly and Also Give Fair Economy When Used on a Certain Car Because the Idling Mixtures Are Too Lean for Operation. Data for Carbureter *VTV* in the Lower Right Corner, an Instrument of 1¼-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.54 In. of Mercury at 59 Deg. Fahr., Show That It May Also Give Improper Idling, Although It Is Better Than Carbureter *UTR* in This Respect

shown in the lower left corner of Fig. 13 explain the reason, as the idling mixtures are too lean for operation. Much better economy can be had at about 15 or 20 m.p.h. than at slightly higher speeds. Excessive leaning is noticed at the higher flow-rates. The metering is rather accurate for an air valve.

Carbureter *VTV*, shown in the lower right corner of Fig. 13 may also show improper idling, although it is better than carbureter *UTR* in this respect. A speed of from 15 to 25 m.p.h., a 15 to 28-cu. ft. per min. flow-rate, will result in the best economy. The three air-valves at these speeds tend to effect the same mixtures but, evidently, some fluttering of the air valves occurs as the results show. Higher flow-rates show more accurate metering.

CONSTANT-VACUUM AND AIR-FUEL-PROPORTIONING TYPES

These two types of carbureter are presented together because of their similarity. A change in the position of the air valve will cause a corresponding relative change in the fuel valve. A few of the constant-vacuum models approach very nearly the air-fuel-proportioning type.

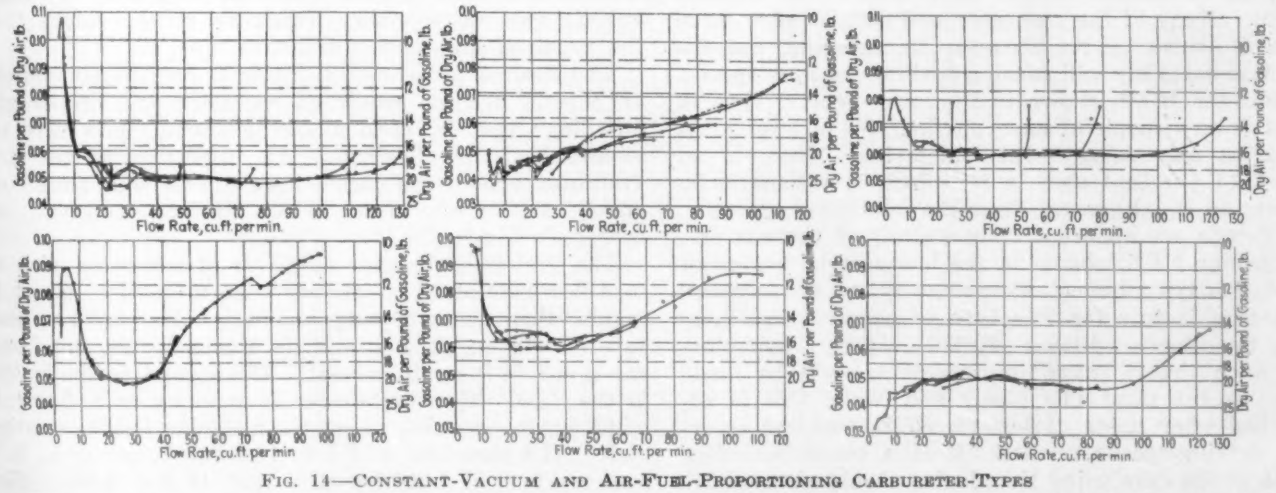

FIG. 14—CONSTANT-VACUUM AND AIR-FUEL-PROPORTIONING CARBURETER-TYPES

These Two Types of Carbureter Are Presented Together Because of Their Similarity. Carbureter *NRS*, of 1¼-In. Nominal Size and an Air-Chamber Absolute-Pressure of 28.59 In. of Mercury at 78 Deg. Fahr., Gives the Results Shown in the Upper Left Corner. It is Part Plain-Tube, Nearly Constant-Vacuum and Air-Fuel Proportioning. The Idling Mixtures Vary in the Proper Manner but the Flow-Rates, from 10 to 35 Cu. Ft. per Min. Are Erratic in Metering. For Carbureter *RSZ*, Constant-Vacuum, of 1-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.60 In. of Mercury at 70 Deg. Fahr., Results Show It Rather Accurate at the Higher Flow-Rates and Level-Road Conditions, but Somewhat Erratic at the Lower Flow-Rates, as Seen in the Upper Central View. The Data on Carbureter *QSS* Are Shown in the Upper Right Corner. The Carbureter Is of 1¼-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.83 In. of Mercury at 77 Deg. Fahr. From Metering Results Shown, Carbureter *QSS* Has Approached Closer to the Ideal Than Has Any Other Model Analyzed. In the Lower Left Corner Carbureter *OSZ* Results Are Presented. It Is of 1-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.40 In. of Mercury at 84 Deg. Fahr. While It Does Not Follow Closely the Ideal Metering Characteristics, Its Accuracy of Metering Is Phenomenal. Carbureter *MRM*, Lower Central View, Is of 1-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 28.51 In. of Mercury at 75 Deg. Fahr. It Exemplifies How Combinations of Lever Arms and Valves May Cause Erratic Metering; It Has an Error of 11 Per cent. The *FEZ* Carbureter Giving the Data Shown in the Lower Right Corner, of 1¼-In. Nominal-Size and an Air-Chamber Absolute-Pressure of 29.05 In. of Mercury at 70 Deg. Fahr. Is a Typical Constant-Vacuum Type, Having a Fair Degree of Accuracy in Metering for This Type

Carbureter *NRS* is rather a peculiar combination as to type; it is shown in the upper left corner of Fig. 14. It is part plain tube, nearly constant vacuum as well as air-fuel proportioning. The idling mixtures vary in the proper manner but the flow-rates from 10 to 35 cu. ft. per min. are erratic in metering. Provision is made for open-throttle enrichment, but the quantity of extra fuel is insufficient for the purpose; only 10-per cent enrichment is effected where 24-per cent enrichment is desired. A rather critical point might occur at the 23-cu. ft. per min. flow-rate, just before the throttle is wide open.

Carbureter *RSZ*, shown in the upper central view in Fig. 14, is rather accurate at the higher flow-rates and level-road conditions, but is somewhat erratic at the lower flow-rates. With proper adjustment at perhaps 10 m.p.h., a loss in economy would be apparent at higher speeds. The only method that would alter this condition would be a change in the design of the metering pin or the air-valve form.

The data on carbureter *QSS*, are shown in the upper right corner of Fig. 14. From the metering results shown, this carbureter has approached the ideal closer than has any other model analyzed. It is admitted that carbureters *SSO* and *KMB* are next in line but, from the car and the engine-requirement viewpoints, carbureter *QSS* is somewhat better. In accuracy of metering it is reliable, even though it be an air-fuel proportioning-device. The criticism offered when comparing the device with the ideal is that it is slightly rich at the lower flow-rates, and cannot be remedied entirely by adjustment.

Another air-fuel-proportioning device, *OSZ*, is shown in the lower left corner of Fig. 14. While not closely following the ideal metering-characteristics, its accuracy of metering is phenomenal. It made no difference whether the device was run on an engine or in the testing plant, the accuracy is the same. Of course, the idling is too rich, as are the mixtures at the higher flow-rates. An air horn, which was used as standard equipment, caused an enrichment of the mixture of more than 40 per cent. Many of the constructional details were cared for, as is shown by the accuracy in metering, but the restriction certainly will cause a fuel loss at high speeds.

Carbureter *MRM*, shown in the lower central view in Fig. 14, is an example of how combinations of lever arms and valves may cause erratic metering. Here is an error of 11 per cent and, in its effect, it automatically subtracts an equal amount from the maximum economy. Other details are apparent from a study of the curves.

Carbureter *FEZ*, shown in the lower right corner of Fig. 14, is a typical constant-vacuum type. Its accuracy of metering is fair for this type of construction. Assuming the other conditions effected properly, the metering is such that a great improvement could be made simply. A car must idle nicely and, when this is accomplished when using carbureter *FEZ*, fuel-loss at ordinary driving-speeds results. It is a recognized fact that one of the cars using this device should show about 17 miles per gal. of fuel. In actual practice the result is about 10 to 12 miles per gal., or about a 40-per cent loss. As was stated, this loss is directly chargeable to improper design.

In this investigation of metering characteristics, 23 different carbureters were studied and tested, 16 of which are reported here in detail. The ones reported are all representative of standard equipment and are not retail replacement-products. Nearly all have defects of some form that cannot allow both economy and performance. Out of the 23 tested, but 4 approached the ideal requirements, the remainder being average or below. As three of the better models have been on the market only a short time, it is evident that a loss of fuel has resulted from the use of other models.

In analyzing the metering, it is expected that acceleration will be provided, independent of metering. From more than a superficial survey, it has been found this is not the usual case and, in some instances, where individual wells were used, more refinement in the effectiveness of the well could be made. The lack of provision for acceleration has caused the fuel loss to be increased materially; the exact amount is indeterminate from the test results, as the metering was considered paramount in any case.

While discussing metering, the results can be made more evident if they are presented in comparison, using some justifiable basis. If the ideal carbureter-requirements are used, complications will arise because none of the carbureters compensate for no load except at the lowest speed. The next best basis is that of the car requirements for a level road, which eliminates most of these difficulties. From Fig. 5, it was observed that the car requirements for a 1¼-in. carbureter were nearly the same as those for a 1-in. size. Using an average of the two, the ideal is expressed in terms of enrichment above the constant ratio of 0.0625 lb. of gasoline per lb. of dry air. Hence, the ideal is so given in Table 2. The commercial-carbureter results are expressed in percentage of enrichment over these required ratios. The critical point on the curves was taken where the mixtures would become leaner than the ideal or show a negative enrichment. A negative enrichment would result in poor operation; hence, it could not be used. At wide-open throttle at any of the four lower speeds, a negative enrichment may be shown as these points of course do not enter into level-road operation. The highest speed was considered as a part of the level-road requirements for, without it, the car could not attain its maximum road-speed. The lower open-throttle conditions of course represent hill-climbing ability. These results may show either leaner or richer values than the required high-power mixtures.

The figures presented in Table 2 for the commercial carbureter are for level-road operation and proper hill-climbing; that is, ideal metering should show zero enrichment at any flow-rate. An inspection of the data from any one of the carbureters proves that none completely fulfills the ideal. Four devices, however, are rather similar to the idea.

The first is carbureter *QSS*. It is somewhat rich up to a flow-rate of 10 cu. ft. per min., a speed of about 10 m.p.h., then the metering is nearly ideal until a flow-rate of 110 cu. ft. per min. is attained. At maximum car-speed, it is again correct. The second device in line is the *SSO*. This carbureter is good up to a flow-rate of 50 cu. ft. per min., where the metering becomes rather rich. At a flow-rate of 7.5 to 10.0 cu. ft. per min., it is somewhat rich, but the rich spot is not wide. This carbureter certainly deserves second place in metering. The third place is allotted to carbureters *NRS* and *KMB*. Considering level-road operation alone, perhaps *NRS* shows the better metering, except at low speeds. At this point the enrichment might be cut slightly by leaning the idling jet. Too lean mixtures are provided for hill climbing, which would hinder the performance at wide-open throttle. Carbureter *KMB* could be improved to show much better metering if the lean spot were eliminated at the 5-cu. ft. per min. air flow-rate. Im-

TABLE 2—METERING CHARACTERISTICS OF CARBURETERS

Carbureter				Percentage of Enrichment at Various Flow-Rates, Cu. Ft. per Min.																	Wide-Open Throttle				
Designation	Type[7]	Mixture-Outlet Type	Nominal Size, In.	2.5	5.0	7.5	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	First	Second	Third	Fourth	Fifth
Ideal[6].....	....	....	....	31.2	5.0	4.3	4.0	2.7	1.3	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	24.0	24.0	24.0	24.0
BBZ	*PT*	Side	½	.....	66.2	39.4	34.7	41.7	35.5	32.0	30.7	26.4	25.0	20.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0
CCZ	*PT*	Side	1	.....	82.3	98.7	59.8	36.9	24.7	20.1	21.4	16.5	13.5	16.0	16.8	18.2	20.8	23.2	.....	.....	.....	−11.7	− 8.8	−5.9	2.0
DCF	*PT*	Side	1	.....	14.0	2.9	5.4	23.6	13.8	13.8	20.0	11.1	8.2	3.9	7.5	9.0	16.6	.....	.....	.....	.....	.....	.....	.....	1.8
GJZ	*AV*	Top	1	0.0	82.8	67.5	42.8	36.9	30.5	26.8	30.6	24.1	16.0	17.4	20.8	20.4	22.4	26.4	.....	.....	.....	4.6	−4.9	−1.9	2.9
HKF	*PT*	Side	15/16	.....	0.0	28.3	29.8	34.1	39.9	45.1	51.0	60.0	72.5	91.7	106.0	.....	.....	.....	.....	.....	.....	17.8	25.0	45.7	76.4
LMZ	*SMJ*	Top	1	0.0	39.5	64.8	74.7	74.2	75.6	73.9	70.3	66.0	66.0	66.6	69.2	73.2	77.9	82.3	.....	.....	.....	−6.2	45.2	50.1	63.7
MRM	*AFP*	Side	1	.....	.....	54.7	36.4	9.6	6.4	6.4	6.6	4.6	8.0	12.2	21.0	30.9	42.7	46.7	47.4	.....	.....	−17.5	−12.0	−6.2	18.9
OSZ	*AFP*	Side	1	4.2	79.2	71.3	47.2	11.5	4.4	0.6	2.3	12.0	44.5	62.8	77.1	78.5	92.2	.....	.....	.....	.....	−15.6	10.0	36.6	59.7
PSA	*PT*	Top	1	.....	0.8	33.1	15.5	4.1	1.7	3.1	4.4	10.4	19.2	27.3	34.7	45.6	.....	.....	.....	.....	.....	−12.1	−8.7	5.2	28.5
RSZ	*CV*	Side	1	.....	11.6	18.7	11.1	21.0	27.7	28.7	35.6	48.7	54.2	59.7	65.2	70.7	81.7	92.8	111.6	.....	6.7	8.2	20.6	33.8	73.2
SSO	*PT*	Top	1	3.4	5.7	17.0	10.0	4.1	5.7	8.2	3.5	0.0	10.0	27.3	27.1	25.1	37.7	45.7	.....	.....	.....	10.2	5.6	8.4	32.6
ABB	*CAAV*	Top	1⅛	.....	0.0	11.7	5.7	8.3	13.1	22.8	30.5	42.2	60.7	72.1	66.7	52.1	47.2	41.8	32.0	.....	.....	−14.5	−2.7	1.1	6.1
EET	*PT*	Side	1¼	.....	.....	0.0	35.0	36.2	34.8	34.0	35.0	30.9	30.9	30.9	29.8	27.5	26.8	25.6	.....	.....	.....	6.9	6.1	5.7	1.2
FEZ	*CV*	Side	1¼	.....	0.0	42.4	56.9	70.4	84.1	85.0	92.3	95.8	96.6	86.2	82.8	80.0	82.0	95.8	116.7	153.8	51.6	57.3	43.3	44.3	11.4
IMN	*CAAV*	Top	1¼	.....	41.5	37.1	31.5	18.7	13.2	23.6	33.9	33.6	34.3	36.7	33.9	29.3	28.4	27.5	25.6	.....	10.9	6.5	78.0	4.6	0.0
JMO	*CAAV*	Top	1¼	0.0	138.5	106.5	73.9	47.0	46.1	62.8	63.7	59.0	59.0	56.0	52.7	52.4	50.6	47.6	45.2	43.7	29.4	27.9	28.4	22.6	40.1
KMB	*CAAV*	Top	1½	51.1	0.0	14.1	14.5	13.2	12.6	18.1	18.1	14.2	17.5	18.5	18.5	24.3	25.7	36.1	94.0	90.0	.....	43.8	55.2	53.2	58.3
NRS	*AFP*	Top	1¼	.....	108.2	54.7	23.0	16.6	6.2	1.7	5.2	4.8	4.4	3.8	0.0	0.0	3.3	4.6	9.0	9.6	−8.0	−9.4	−10.4	−1.2	0.0
QSS	*AFP*	Top	1¼	.....	26.4	14.3	5.5	4.6	3.3	2.9	3.6	0.5	0.5	1.5	2.8	0.0	0.0	2.2	16.0	17.1	.....	7.0	5.7	5.1	4.4
TSM	*PT*	Top	1¼	.....	60.2	77.3	12.8	33.9	34.0	33.8	33.1	31.7	30.7	30.3	29.8	29.2	28.4	27.7	26.9	26.0	.....	−0.6	−5.3	−6.8	0.0
UTR	*AV*	Side	1¼	.....	15.4	60.2	58.0	45.4	37.0	46.1	55.7	47.7	56.6	44.2	39.4	34.9	31.1	30.1	28.8	0.0	19.0	22.1	15.5	5.7	0.0
VTV	*AV*	Side	1¼	0.0	79.7	78.3	55.0	35.8	33.5	36.0	42.9	49.2	47.8	40.8	28.1	29.8	25.7	25.7	35.1	...	6.0	16.1	14.3	2.7	10.5
XZZ	*PT*	Side	1¼	.....	.....	52.4	48.6	41.4	35.0	29.6	26.0	20.4	16.7	15.7	15.4	15.2	17.0	22.2	.....	.....	.....	22.0	−6.0	−7.2	0.0

[6] Variation of ideal mixtures above the ratio 0.0625 lb. of gasoline per lb. of dry air.

[7] *PT*=plain tube; *AV*=air valve; *SMJ*=succeeding multiple jet; *AFP*=air fuel proportioning; *CV*=constant vacuum; *CAAV*=compensated auxiliary air valve.

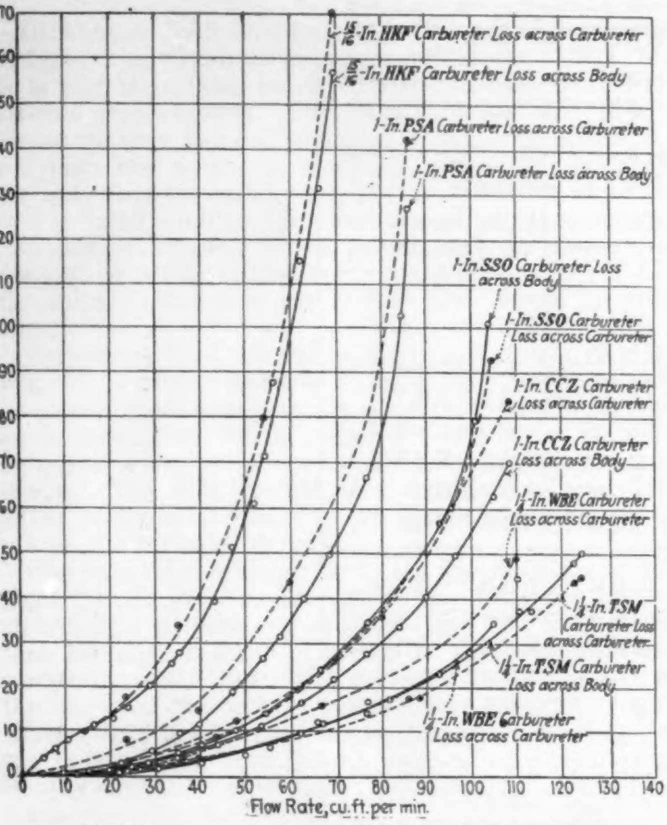

FIG. 15—BODY PRESSURE-LOSS OF PLAIN-TUBE CARBURETERS
The Curves Are All Characteristic of This Type of Carbureter. Device *HKF* Shows a High Power-Loss; *PSA* Is Small for a 1-In. Model; *SSO*, Also a 1-In. Model, Has Much Less Loss Than *PSA*; *CCZ* Is the Least Constricted of All in the 1-In. Class; the Plain-Tube Carbureter of 1¼-In. Nominal-Size, Such as *WBE* and *TSM*, Is Not Nearly So Constricted as Many of the Smaller Models

mediately, a 12-per cent enrichment could be cut, bringing the metering very close to that desired, especially up to a flow-rate of 70 cu. ft. per min.

To go to the other extreme, attention is called to carbureters *FEZ* and *HKF*. Noting the values of the enrichment at the various flow-rates will illustrate the fuel losses. Carbureter *HKF* is in wide use, and no doubt is partly responsible for the vast annual wastage of gasoline.

CARBURETER FRICTIONAL LOSS

Pressure-loss across a carbureter can be used as a means of judging the effect on its power capacity. Two readings were taken, one of the carbureter-body and one of the total pressure-loss. The body pressure was taken at a point directly behind the throttle-valve, yet far enough removed to eliminate any throttle-valve effects. The total pressure-loss piezometer-tap was inserted as close to the outlet flange as possible. In some instances it was taken from a spacer plate just beyond the outlet flange. In all cases, the pressure-loss was read in terms of static head by piezometer-taps inserted normal to the direction of flow.

After a few tests, it was found that serious difficulty would be encountered if the actual drop across the whole device was necessary. The throttle-valve divides the flow, thus making the true value of the loss nearly impracticable to determine. The body pressure-loss as taken nearly represents the true conditions, although there are perhaps small errors due to turbulent flow. The frictional loss in the body is, in all cases, taken as a basis for comparison.

The constriction or pressure-loss across the plain-tube carbureters heretofore described is presented in Fig. 15. The curves are all characteristic of this type of carbureter. Device *HKF* shows a high relative power-loss. At the maximum speed of the car on which it is used, a loss of nearly a 120-in. head of water is obtained. Device *PSA* is small for a 1-in. model, as indicated by a head loss of a 130-in. head of water at a flow of 87 cu. ft. per min. A larger venturi would aid the metering materially. In the next device, *SSO*, the nominal rating is the same but the loss is much less. The loss shows a rapid increase above 50 cu. ft. per min. Seldom, however, would the device be used above a flow-rate of 95 cu. ft. per min. The resulting frictional loss of 60 in. of water is lower than those previously mentioned but is too high to show the best power. Carbureter *CCZ* is

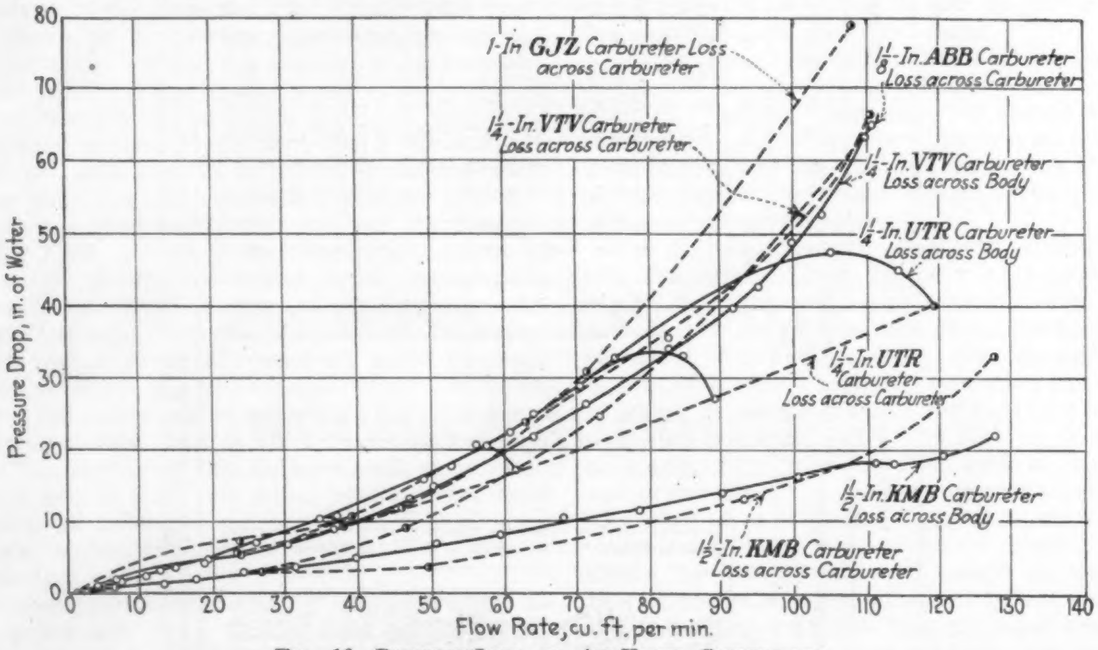

FIG. 16—PRESSURE-LOSS OF AIR-VALVE CARBURETERS
With the Use of Air-Valves, It Might Be Expected That the Pressure-Loss across the Carbureter Would Be Lower Than That of the Plain-Tube Carbureters. The Curves Shown Herein Provide a Basis for Comparison. Carbureter *KMB* Has a Very Low Constriction but, Since It Must Be Rated as a 1½-In. Size, the Loss Is Not So Low as Appears at First Glance

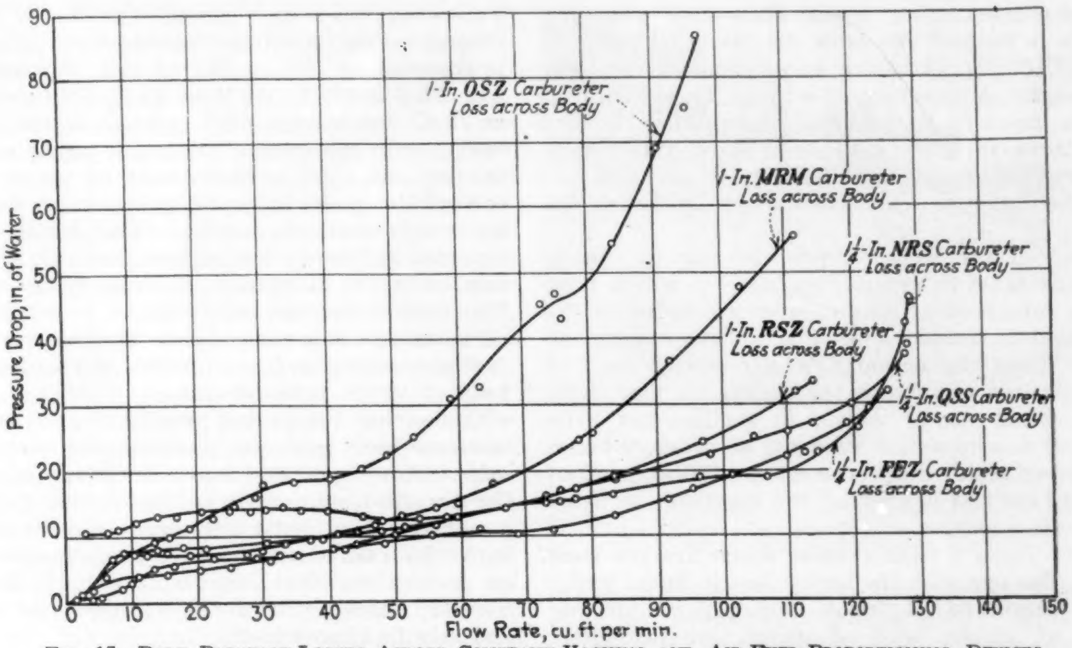

FIG. 17—BODY PRESSURE-LOSSES ACROSS CONSTANT-VACUUM AND AIR-FUEL-PROPORTIONING DEVICES

As Shown, Friction-Loss Results Are Very Different for Carbureters Embodying both Air-Valves and Fuel-Valves. The Majority of the Constant-Vacuum and Air-Fuel-Proportioning Types Show Low Pressure-Loss. This Is True of the Later Models Developed. For Carbureter *OSZ the Excessive* Loss Is Due to Improper Air-Horn Design

the least constricted of all in the 1-in. class. At a 95-cu. ft. per min. flow-rate, there is a loss of only 47 in. of water; hence, the power capacity should be nearly the maximum. The plain-tube carbureter of a 1¼-in. rating is not nearly so constricted as many of the smaller models. A loss of only 50 in. of water at a 125-cu. ft. per min. flow-rate is rather low.

With the use of air valves, it might be expected that the pressure loss across the carbureter would be lower than that of the plain-tube carbureters. An inspection of the five carbureters included in this class, as indicated in Fig. 16, will show the comparison. Carbureter *KMB* has a very low constriction but, as it must be rated as a 1½-in. size, the loss is not so low as is noted at first glance.

In carbureters embodying both air-valves and fuel-valves, the friction-loss results are very different, as is shown in Fig. 17. The majority of the constant-vacuum

TABLE 3—COMPARISON OF CARBURETER-BODY PRESSURE-LOSSES

Carbureter					Maximum Cubic Feet per Minute per Square Inch, Corrected	Cubic Feet per Minute per Square Inch at Inches of Water, Pressure-Loss							Maximum Pressure-Loss at Maximum Flow-Rate, (a)
Designation	Type[8]	Mixture-Outlet, Type	Nominal Size, In.	Actual Cross-Sectional Area, Square Inch		10	20	30	40	50	60	70	
ABB	*CAAV*	Top	1⅛	1.353	83.6	36.1	50.2	60.0	67.6	74.8	81.4	....	63.0
BBZ	*PT*	Side	½	.836	82.2	24.5	38.4	47.5	53.2	57.8	61.5	64.6	211.0
CCZ	*PT*	Side	1	1.080	103.3	47.6	63.8	75.7	85.0	92.2	98.5	103.7	.....
DCF	*PT*	Side	1	1.049	94.1	37.8	50.3	59.3	66.3	72.6	78.1	82.6	145.0
EET	*PT*	Side	1¼	1.623	64.7	25.5	36.0	43.7	50.8	57.1	62.1	....	65.4
FEZ	*CV*	Side	1¼	1.623	78.9	....	68.8	77.7	....	....	....	....	32.4
GJZ	*AV*	Top	1	1.108	99.4	34.6	54.4	64.6	73.0	80.5	87.4	94.2	79.2
HKF	*PT*	Side	15/16	.994	71.2	13.9	29.0	38.0	44.0	48.5	52.1	54.9	157.8
IMM	*CAAV*	Top	1¼	1.623	74.2	29.6	50.4	65.2	....	....	....	....	37.9
JMO	*CAAV*	Top	1¼	1.623	76.5	16.1	29.9	42.4	54.8	66.7	75.6	....	64.4
KMB	*CAAV*	Top	1½	2.237	58.2	30.8	56.2	....	....	....	....	....	22.0
LMZ	*SMJ*	Top	1	1.227	91.2	34.9	51.1	64.3	73.4	80.0	85.5	90.5	71.9
MRM	*AFP*	Side	1	1.108	103.1	36.2	64.8	78.6	88.8	97.9	....	....	.....
NRS	*AFP*	Top	1¼	1.623	81.5	34.1	64.7	78.0	81.0	....	....	....	.....
OSZ	*AFP*	Side	1	.994	100.0	16.7	44.7	60.1	69.6	82.7	88.8	93.7	86.6
PSA	*PT*	Top	1	1.108	79.5	33.8	44.2	52.2	58.3	63.3	67.9	71.8	122.8
QSS	*AFP*	Top	1¼	1.623	80.9	30.6	55.1	75.9	....	....	....	....	38.7
RSZ	*CV*	Side	1	1.108	105.7	36.2	78.9	99.8	....	....	....	....	33.6
SSO	*PT*	Top	1	1.108	95.5	42.4	56.0	66.2	74.6	81.9	87.2	90.7	101.9
TSM	*PT*	Top	1¼	1.623	78.7	38.5	54.3	64.0	71.4	77.7	....	....	.....
UTR	*AV*	Side	1¼	1.623	75.2	25.5	44.0	60.3	75.3	....	....	....	.....
VTV	*AV*	Side	1¼	1.623	70.1	24.5	37.8	48.7	57.9	64.2	68.3	....	65.3
XZZ	*PT*	Side	1¼	1.623	64.2	31.4	41.7	49.6	56.0	60.5	64.3	66.7	68.6

[8] *PT* = plain tube; *AV* = air valve; *SMJ* = succeeding multiple jet; *AFP* = air fuel proportioning; *CV* = constant vacuum; *CAAV* = compensated auxiliary air valve.

and air-fuel-proportioning types show low pressure-losses. This is true of the later models developed. In carbureter *OSZ*, the excessive loss is due to improper air-horn design. A flow-rate of 120 cu. ft. per min. at only a 30-in. head of water as a pressure-loss is very good, and three of the carbureters show this result. From a power viewpoint the constant-vacuum and air-fuel-proportioning types are considered as being the best.

To present all the data on pressure-loss in concise form, it is advisable to revert to a table in which flow-rates can be compared at various pressure-losses. Table 3 shows these data computed on an actual cross-sectional-area basis. Thus the actual flow per square inch of cross-sectional area eliminates the carbureter size, especially the nominal rating which, in reality, has little meaning. The flow-rates are reported at pressure-losses of 10-in. head of water difference up to a 70-in. head of water. Where the loss is greater, the maximum is listed in the succeeding column.

The data in Table 3 clearly show which are the least constricted. The one with the lowest loss is found under the section designated as "cubic feet per minute per square inch at inches head of water, pressure-loss." Following down the column for 30-in. pressure-head, several values lie rather close together. Carbureter *CCZ* is reported as 75.7 cu. ft. per min. flow-rate per sq. in.; and *FEZ* as 77.7, *MRM* as 78.6, *NRS* as 78.6 and *QSS* as 75.9. Carbureter *RSZ* is much better in this respect than any of the others; it attains a flow-rate of 99.8 cu. ft. per min. At a 40-in. head of water pressure-loss, one of the plain tubes is approaching the flow-rate of air-fuel-proportioning type. The *MRM* carbureter is reported as having the highest flow-rate, 88.8 cu. ft. per min., with the plain-tube *CCZ* carbureter a close second. The *QSS* carbureter is about on a par with the *NRS* carbureter, a composite device of the plain-tube and air-fuel-proportioning type, for the third place, at a 40-in. head of water pressure-loss.

Comparing the power possibilities on the unit cross-sectional basis is unique, because size is eliminated. The only factor that could cause a change in the rating is the throttle loss. As was stated, this factor was such a variable that little reliance could be placed on the data. In most cases, the body pressure-data can be used as correct for that representative of the entire carbureter, although, if thick throttle-valves are used, the loss may be exececessive.

TABLE 4—PERCENTAGE OF ENRICHMENT PER DEGREE OF TEMPERATURE RISE

Carbureter		Air-Temperature, Deg. Fahr.		Air Flow-Rate, Lb. per Min.								
Designation	Type[9]	Initial	Final	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
ABB	*CAAV*	69	125	0.344	0.166	0.034	0.048	−0.073	0.013	0.058	0.035	......
		69	175	0.151	0.073	0.015	0.072	−0.024	0.005	0.036	0.041	......
CCZ	*PT*	73	125	0.218	0.000	0.060	0.175	0.073	0.091	0.146	0.093	......
		73	175	0.127	0.040	0.050	0.121	0.081	0.075	0.186	0.110	......
DCF	*PT*	85	150	......	0.000	0.167	0.050	0.129	0.077	0.168	......	......
EET	*PT*	67	127	0.161	−0.035	0.090	0.043	0.060	0.000	0.075	......	......
		67	175	0.166	0.019	0.055	0.062	0.066	0.040	0.077	......	......
FEZ	*CV*	67	125	0.218	0.153	0.026	0.033	0.054	0.066	0.109	0.185	0.183
		67	174	0.158	0.099	0.025	0.038	0.029	0.028	0.101	0.207	0.161
GJZ	*AV*	80	127	0.277	0.184	0.124	0.093	0.083	0.082	0.111	0.098	......
		80	180	0.260	0.170	0.071	0.080	0.118	0.073	0.086	......	......
HKF	*PT*	57	125	0.636	0.314	0.192	0.152	0.147	0.222	......	......	......
		57	175	0.471	0.322	0.214	0.187	0.167	0.204	......	......	......
JMO	*CAAV*	64	128	0.278	0.479	0.296	0.303	0.218	0.230	0.256	0.270	0.206
		64	177	......	0.160	0.189	0.155	0.150	0.137	0.150	0.159	0.116
KMB	*CAAV*	67	126	0.186	0.236	0.194	0.206	0.188	0.216	0.209	0.264	0.167
		67	178	......	0.142	0.173	0.157	0.147	0.179	0.179	0.263	0.128
LMZ	*SMJ*	80	125	0.163	0.135	0.113	0.084	0.087	0.089	0.094	0.058	......
		80	175	0.077	−0.051	0.044	0.076	0.066	0.070	0.070	0.016	......
MRM	*AFP*	58	130	......	0.034	0.017	0.068	0.191	0.237	0.222	0.149	......
		58	176	......	0.133	0.138	0.155	0.252	0.294	0.227	0.159	......
NRS	*AFP*	77	130	......	0.156	0.429	0.211	0.145	0.016	0.124	0.173	......
		77	176	......	0.000	0.157	0.155	0.078	0.038	0.114	0.170	......
QSZ	*AFP*	74	129	0.226	0.135	0.102	0.167	0.162	−0.014	0.153	......	......
		74	173	0.128	0.166	0.078	0.215	0.159	0.125	0.146	......	......
PSA	*PT*	59	129	0.258	0.267	0.186	0.241	0.155	0.147	0.150	......	......
		59	175	0.056	0.154	0.132	0.130	0.076	0.073	......	......	......
QSS	*AFP*	80	127	0.218	0.085	0.190	0.083	0.148	0.070	0.046	0.116	......
		80	176	0.188	0.174	0.135	0.079	0.129	0.074	0.097	0.125	......
RSZ	*CV*	67	126	1.038	0.870	0.368	0.107	0.014	0.000	0.010	0.046	......
		67	177	......	......	0.149	0.116	0.050	0.059	0.082	0.119	......
SSO	*PT*	57	125	−0.241	0.105	0.055	0.020	0.090	0.065	0.081	0.110	......
		57	175	−0.322	0.006	0.000	0.040	0.099	0.077	0.089	0.097	......
TSM	*PT*	67	125	0.000	0.081	−0.133	−0.103	−0.045	0.031	0.061	0.051	0.036
		67	175	−0.198	0.014	−0.035	−0.025	−0.011	0.017	0.028	0.015	−0.011
UTR	*AV*	65	123	0.138	0.000	0.140	0.046	0.036	0.015	0.016	0.055	0.048
		65	173	0.050	−0.018	0.112	0.044	0.045	0.051	0.072	0.078	......
VTV	*AV*	60	128	0.030	0.045	0.177	0.182	0.091	0.040	0.048	0.084	0.132
		60	175	−0.081	0.024	0.215	0.183	0.112	0.073	0.078	0.116	......
XZZ	*PT*	72	125	0.137	0.200	0.057	0.075	0.102	0.075	0.094	0.129	......
		72	175	0.242	0.130	0.057	0.068	0.071	0.076	0.088	......	......
		72	230	......	0.091	0.051	0.059	0.065	0.071	0.084	......	......

[9] *PT* = plain tube; *AV* = air valve; *SMJ* = succeeding multiple jet; *AFP* = air fuel proportioning; *CV* = constant vacuum; *CAAV* = compensated auxiliary air valve.

Effect of Temperature Change

The purpose of this type of test is to determine in a general way the change in mixture-ratios throughout the entire flow-rate range caused by preheating the air. With the change of entering-air temperature, the fuel temperature will be increased correspondingly in the bowl and the nozzle of the carbureter. No attempt was made to record the fuel temperature in the carbureter bowl. That temperature could be recorded, but would not necessarily be the temperature at which the fuel was metered. The main purpose was to show the general effect at all flow-rates. Time did not permit evaluating the exact change throughout a wide range of temperatures at one flow-rate, with regard to weight.

To present the detail graphs would occupy too much space; therefore Table 4 was prepared. It shows the data at the three temperatures run, and the results at the various flow-rates. The change is given in terms of percentage of enrichment per degree Fahrenheit, computed from the lowest temperature run.

The values noted vary widely for any one carbureter throughout its range of flow-rates. The design of the carbureters affects the results appreciably. Some of the factors are: (*a*), type of carbureter, (*b*) method of air-bleeding the fuel nozzle, (*c*) design and number of fuel orifices and (*d*) method of throttling the fuel-delivery nozzle by a needle valve.

In the plain tube, where air-bleeding is provided on the main jet, a change from a low to a medium temperature may cause a certain enrichment. The same increment from the intermediate temperature may show only a slight enrichment or perhaps a tendency toward leaning the fuel-content of the charge. The air-bleeding in this discussion is of the same temperature as the main stream. Another peculiar case is that of a fuel nozzle throttled by a needle valve on the delivery side. It appears that this arrangement is very sensitive to any change in the temperature. Where the average model will show a variation of from 0.07 to 0.10 per cent per deg. fahr., this type shows from 0.15 to 0.32-per cent enrichment. In some cars a 100-deg. change from starting to ordinary running temperatures under the hood will occur; hence, this carbureter would show an enrichment of from 15 to 32 per cent, depending on the speed of the car with regard to the air-flow-rate. This enrichment, when computed as a fuel loss, is between a 13 and a 24-per cent wastage. The construction with the throttling needle of the fuel nozzle on the interior of the nozzle is the next design causing a great enrichment. Where more than one fuel nozzle is used and their range overlaps, the results from this construction may vary in different ways. In all of the work, the design of the fuel nozzle or the orifice may cause the same type of carbureter to show very different results.

The principal thought involved is the magnitude of the mixture-ratio change that can be charged directly to the carbureter. This change is dependent on the type of carburetion system; (*a*) the method of vaporizing the charge and (*b*) the design of the carbureter. Where cold starting is concerned, engine temperature is the most important factor when designing a system for automatic control.

As has been shown, the carbureter delivers leaner mixtures as the temperature drops. The engine requires richer mixtures at the lower temperatures.[10] The carbureter thus gives the reverse of that desired. It is no doubt possible that the problem of providing the

[10] See The Journal, January, 1923, p. 66; see also Purdue University Engineering Experiment Station Bulletins Nos. 5 and 11.

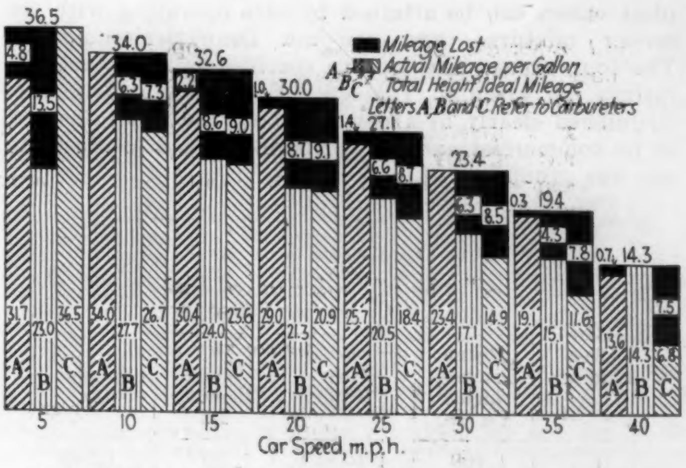

Fig. 18—Carbureter-Test Results Applied to Small Cars
The Total Height of the Column Is the Ideal Fuel-Consumption Mileage. Carbureter *A* Gives Ideal Mileage at 10 and at 30 M.P.H. The Critical Point of Carbureter *C* Is at Low Speeds; It Represents a More Nearly Standard Product for This Type of Car

proper mixtures for engine requirements thermostatically may be worked-out satisfactorily. This control of course must be embodied in any one given carbureter to govern its inherent metering with regard to temperature properly.

Carbureter Data Applied to Cars

Using the metering characteristics of some of the carbureters tested in connection with car and engine data, as presented in the first part of this paper, the ideal economy on level roads can be computed as well as that which should result from any one carbureter.

The purpose in presenting these last few graphs is to average certain classes of automobile with respect to weight and maximum speed, which immediately involves engine size, gear ratio and wheel diameter, and to show just what ought to be expected in economy. These so-called ideal values are computed from tests taken from various sources. The condition of the cars is normal, as they were received directly from the driving public; the engine efficiency is normal also, being averaged from several engine tests in the laboratory. The mixture-ratios computed for the carbureter and used in the compilation of the ideal mileage per gallon were worked out from research data and are reported herein. The

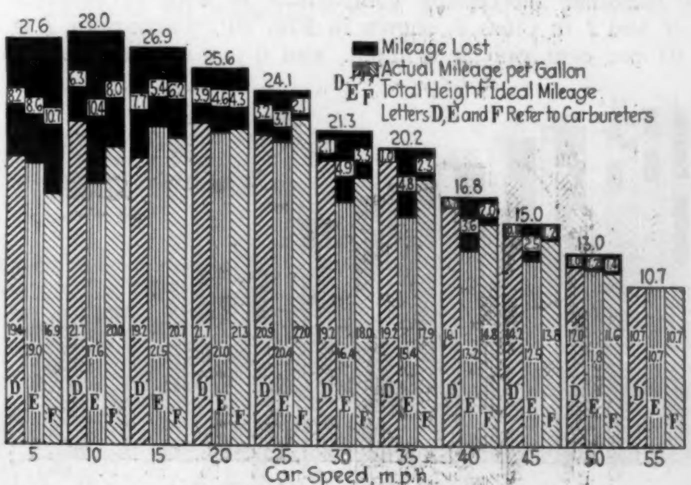

Fig. 19—Carbureter-Test Results Applied to Cars of 2700-Lb. Class
The Fuel-Consumption Mileages Are Computed and Are Shown from 5 to 55 M.P.H., the Latter Being the Maximum Speed of the Vehicle

ideal values can be attained by cars operating with the proper mixtures, and are not theoretical qualities. The four groups selected are specified by their average ratings, as given in Table 5. Each class can be distinguished clearly by the weight and the other factors, so no commercial names need be mentioned to illustrate any one group.

TABLE 5—CLASSIFICATION OF CARS

Car-Class Number	Average Values			
	Piston Displacement, Cu. In.	Gear Ratio	Wheel Diameter, In.	Weight, Lb.
1	160	4.10 to 1	30	1,790
2	217	4.30 to 1	32	2,700
3	225	5.00 to 1	33	3,250
4	336	4.22 to 1	33	4,500

The data as computed are shown in Figs. 18 to 21 inclusive. In every case the total height of the column is the ideal mileage at any one car-speed. With these data serving as a background, 11 different carbureters are used to illustrate the mileage that can be expected in actual operation. These results are presented by the height of the cross-hatched columns.

Three different carbureters are placed in Class 1, Fig. 18, and the full-consumption mileages computed are shown from 5 to 40 m.p.h., the latter being the maximum speed of the car. Carbureter *A* results in the ideal mileage at speeds of 10 and 30 m.p.h. The other speeds approach the required mileage closely; the only exception is a 5-m.p.h. speed, at which a 13-per cent loss is apparent.

Carbureter *C* represents a more standard product for this type of car. Its critical point is at low speeds, or 5 m.p.h. At the next higher speed, the loss is 21 per cent; at 25 m.p.h., the loss is 32 per cent; at the maximum car-speed, the loss grows to 53 per cent. In other words, with this carbureter, a condition at which more than one-half of the fuel is wasted exists. How directly in contrast this device is when compared to carbureter *A*. Carbureter-test results for cars of the 2700-lb. class are shown in Fig. 19.

Another interesting comparison is with carbureters *H* and *I* in Class 3, shown in Fig. 20. Carbureter *I* is 21 per cent rich at 5 m.p.h., and 6 per cent rich at 10 m.p.h. but, at nearly all of the higher speeds including the maximum, 65 m.p.h., the results are ideal. Now compare device *H* which is correct at 5 m.p.h., 23 per cent rich at 10 m.p.h. and 37 per cent rich at 30 and 35 m.p.h., and even a 39-per cent loss is shown above the high-power mixture at 65 m.p.h. In Fig. 21, carbureter-test results for cars of the heavy class are shown.

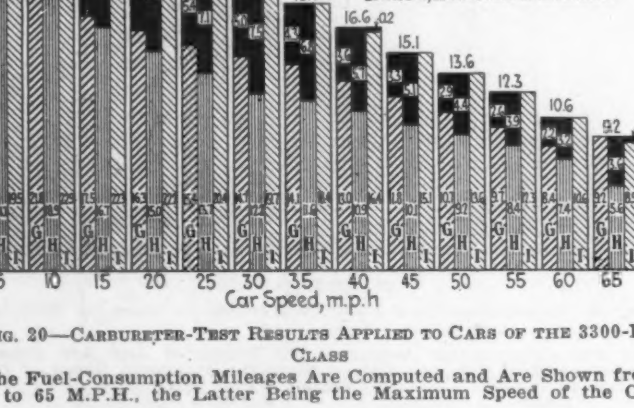

FIG. 20—CARBURETER-TEST RESULTS APPLIED TO CARS OF THE 3300-LB. CLASS
The Fuel-Consumption Mileages Are Computed and Are Shown from 5 to 65 M.P.H., the Latter Being the Maximum Speed of the Car

In the four figures under discussion, various other comparisons can be made to illustrate that we forget economy is sacrificed needlessly in the desire to get performance. Proper design and an intimate knowledge of the resulting mixtures properly fed to the engine can lead to economy as well as the desired performance-features. These can be had without cutting the maximum speed of the car or sacrificing its hill-climbing ability. The factors considered in the charts are only for level-road conditions. In many of the cases, the critical points occur at flow-rates such that hill-climbing ability would not be sacrificed. The two better devices illustrated, *A* and *I*, have provision made for this requirement.

As has been stated, the mixtures were considered to be vaporized and distributed properly. The acceleration proved independent of the metering or, at least, was effected by compromising the metering at constant flow. Many of the devices could not hope to show acceleration when operating under the economy conditions. With a mileage return as shown for most of the devices, then the mixtures are usually sufficiently rich to allow acceleration.

For the mass of the carbureters of the industry improvements might be made by:

(1) Providing proper mixtures consistently throughout the flow-rate range for engine load and speed; or (*a*) level-road operation, (*b*) hill climbing at full load and (*c*) idling

(2) Use of a fully developed accelerating-well independent of metering at constant flow and providing high-power mixtures instantaneously and temporarily

(3) Less constriction across the carbureter, insuring full power when required

(4) Atomization as fine as possible in combination with the foregoing requirements

(5) Proper vaporization or distribution, which insures the fulfilment of items (1), (2) and (3)

Many details such as starting, warming, fixed adjustments and the like are beyond the scope of this paper and cannot be included herein.

SUMMARY

DESIRED CHARACTERISTICS

(1) The engine must develop maximum power at wide-open throttle

(2) Maximum efficiency must be maintained wherever possible

(3) Proper acceleration must be provided when using economical mixtures

CAR CARBURETION-REQUIREMENTS

(4) Vaporization and distribution must be correct in all cases

(5) Each car has its individual mixture requirements, but the average requirements of each car-class will suffice in a practical way

(6) An average of the cars of the 1¼-in.-carbureter class requires nearly the same mixtures at the lower flow-rates as those of the 1-in.-carbureter class. The variation is mainly that slightly

richer mixtures are required at the same flow-rates. The 1½-in. class is 7 per cent richer at certain lower flow-rates

(7) A straight-line mixture does not suffice for level-road performance

COMMERCIAL-CARBURETER TESTS

(8) Carbureter test plant and four-cylinder-engine conditions show the same characteristic metering results. The actual value of the mixture will check in most cases, but some types do not check on comparison

(9) The results of tests show that 4 carbureters out of 23 tested approach ideal metering-requirements. Two of them nearly fulfill the requirements

(10) Critical or breakdown points in metering may occur at any flow-rate, depending on individual-carbureter design

(11) Most devices could improve car economy materially by providing means for full-load compensation for power

(12) Better acceleration devices are necessary

(13) The constant-vacuum type of carbureter shows maximum flow for minimum constriction. The fuel-air-proportioning type ranks second

(14) The plain-tube type, as usually designed, is found to be the most constricted

(15) Of the carbureters tested, 26 per cent should allow maximum power; 30 per cent are very constricted and cause a high loss in engine power; the remaining 44 per cent are responsible for only average power-losses

(16) The effect of the intake-air temperature upon any carbureter depends on (*a*) the type of carbureter, (*b*) the method of air-bleeding the fuel nozzle, (*c*) the design and number of fuel orifices and (*d*) the method of throttling the fuel-delivery nozzle by the use of a needle valve

(17) An increase in the air temperature usually causes an enrichment of the mixture. The variables involved permit no definite statement as to the effect on all types, the variation being approximately from 5 to 15 per cent enrichment per 100 deg. for ordinary conditions

CARBURETER DATA APPLIED TO A CAR

(18) The normal carbureter as built and applied to cars will show the best economy at a car speed of about 20 to 30 m.p.h.

(19) The computed ideal mileage decreases with an increase of the car speed

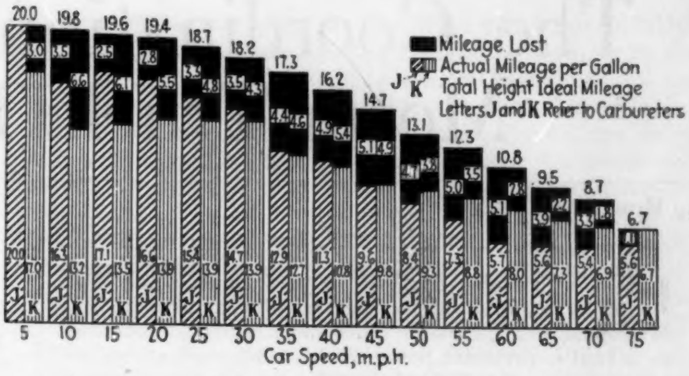

FIG. 21—CARBURETER-TEST RESULTS APPLIED TO CARS OF THE HEAVY CLASS

The Fuel-Consumption Mileages Are Computed and Are Shown from 5 to 75 M.P.H., the Latter Being the Maximum Speed of the Car

(20) When all carbureters are adjusted for performance, a fuel loss of 26 per cent is shown at a car speed of from 15 to 20 m.p.h. At 25 to 30 m.p.h., the loss is also 26 per cent; at 35 to 40 m.p.h., it is about 30 per cent

CONCLUSIONS

The tests in all cases have been run in a normal way, and the results represent average car-conditions. The computed results may not have the nice accuracy usually expected from research work, but they do present usable data that are of prime importance to the automotive industry. The long discussed question as to the advisability of using straight-line mixture-ratios may be solved more nearly.

The data given on commercial carbureters have been presented so that it is hoped the constructive criticisms offered are accepted in the spirit in which they are given. The automotive industry is wasting too much fuel. The wastage values shown are mainly from an engineering-design viewpoint. Actual tests on cars driven by the public would show somewhat higher losses because of poor vaporization or manifolding. The automotive engineer at least can aid in giving the public better devices that will eliminate a portion of the fuel losses and some of the indirect losses resulting from poor carburetion. Much credit is due O. Chenoweth, formerly associated with the Purdue University Engineering Experiment Station, for assistance in the tests and for computations of the results set forth in this paper.

THE FARMER

THE glory of the farmer is that, in the division of labors, it is his part to create. All trade rests at last on his primitive activity. He stands close to nature; he obtains from the earth the bread and the meat. The food which was not, he causes to be. The first farmer was the first man, and all historic nobility rests on the possession and the use of land.

All men keep the farm in reserve as an asylum where, in case of mischance, to hide their poverty, or a solitude, if they do not succeed in society.—Ralph Waldo Emerson.

The Coordination of Railroad and Motor-Truck Transportation

By ROBERT C. WRIGHT[1]

ANNUAL MEETING PAPER

LACK of reliable data as to performance and cost and the rapid strides that have been taken in the development of the motor truck have hitherto prevented an actual experiment being made to demonstrate clearly the value of the motor truck as a possible adjunct to rail transportation; but the definite extent of the field of usefulness of the motor vehicle cannot be fully determined until motor transporters are charged with all the common carrier responsibilities commensurate with the privileges they enjoy in the use of the public highways. As a result of study, the Pennsylvania Railroad System has become convinced that the motor truck can cooperate with the steam railroad in three lines of activity: (*a*) in substituting motor trucks for rail transportation for handling short-haul less-than-carload traffic, (*b*) in motorizing terminals and (*c*) in door-to-door delivery service. All these can be combined naturally into a final plan, or each undertaken independently of the others.

Among the advantages of the motor truck in handling short-haul less-than-carload traffic are said to be a reduction in the number of handlings required, less exacting packing and rapidity of service. Locating freight stations at various points throughout the city for advantageously procuring competitive traffic necessitates duplicating certain cars and moving others in and about the terminals. But if all less-than-carload freight were unloaded and loaded from one properly constructed station, a large amount of transferring would be saved, heavier through-loading would be possible and the service would be more regular. It is asserted that a door-to-door delivery service would save the 2 days' free time now allowed for removing freight, save platform space, insure the prompt delivering of freight and prolong the adequacy of existing stations. This service, it is believed, could be rendered best by a separate company, responsible to the traders for the service and simply utilizing the rail carrier from station to station under a proper contract.

The conclusions drawn are that the field of the motor vehicle should be determined, that the motor vehicle should assume all the responsibilities commensurate with the privileges it enjoys and that rail, electric-line and motor truck transportation should be coordinated, each serving its own field and avoiding competition.

THE conclusions of Special Commitee IV, appointed by the president of the Chamber of Commerce of the United States of America to report on the Relation of Highways and Motor Transport to Other Transportation Agencies, outlined the policies for the guidance of those interested in the subject, and are the consensus of opinion of a number of persons representing various occupations and business interests, who have given the matter study; the danger is thus avoided of their being considered the opinion of any one man who might be biased through an intensified study of a particular subject. It is very gratifying, therefore, to the members of Committee IV to know that their conclusions were confirmed by the Transportation Conference held in the City of Washington on Jan. 11.

For a number of years, students of transportation efficiency have had their eyes on the motor vehicle as a possible adjunct to rail transportation, but the lack of reliable data as to performance and costs, together with the rapid strides made in the development of the motor vehicle, has prevented a clear determination as to how and when to make an actual experiment along their lines of thought. As time passed, and more information developed, it became apparent that there was a "field" of transportation in which the motor vehicle would prove to be the economic transportation machine.

However, the definite extent or limitations of this field cannot be fully determined until motor transporters over the highways are charged with all the proper common-carrier responsibilities, taxation and regulation, commensurate with the privileges they enjoy in the use of the public highways; but this can be brought about if the recommendations made by the Transportation Conference are seriously taken in hand and worked out along sane and practical lines.

The problem from the more concrete standpoint of the railroad was complicated somewhat further by the unknown attitude of what we railroad men know as "the public"; but the railroads have, nevertheless, been studying the problem for some time in an effort to determine

(1) In what definite manner the motor truck could be taken into partnership
(2) How a start could be made in this direction

The result of this study on the part of the Pennsylvania Railroad System was that the following conclusion was reached: that there are three branches of rail operation with which the motor truck could be effectively coordinated, all of which could be combined naturally into a final plan; and each of which, on the other hand, could be undertaken independently of the others, and each progressed as the situation developed in a practical way. These three activities are as follows:

(1) Utilization of motor trucks as a substitute for the railroads in handling short-haul less-than-carload traffic
(2) Motorization of terminals
(3) Door-to-door delivery service

SUBSTITUTING MOTOR TRUCKS FOR STEAM RAILROADS IN HANDING SHORT-HAUL LESS-THAN-CARLOAD TRAFFIC

By short-haul less-than-carload traffic we mean small lots of freight, which, under the tariffs, are loaded and unloaded by the carrier, and transported by rail for distances up to, say, 25 or 30 miles. Under the ordinary method of handling this traffic, the freight must be loaded on to the shipper's dray, hauled to the freight station, unloaded at the platform, picked up from the platform, loaded into a freight car, transported generally to the transfer-station, unloaded onto a platform, loaded into a way freight car, unloaded at the destination, there loaded onto the consignee's dray and unloaded finally at the door or warehouse of the consignee.

This method involves eight handlings of the freight,

[1] General traffic manager, Pennsylvania Railroad System, Philadelphia.

whereas, if it were conveyed entirely by motor trucks, a loading at the shipper's door and an unloading at the consignee's door would be the only handlings required; that is to say, two handlings by the latter method as against eight handlings by the former; and, at a time when labor is becoming an increasingly heavy factor in transportation cost, it requires little thought to observe the possible economy of substituting motor trucks for rail transportation for handling short-haul small-lot freight.

Other advantages favor the motor truck for short hauls, such as the less exacting packing that is necessary to protect the freight for movement by rail and the rapidity of service, and the like.

It might seem that the wise thing for the railroads would be to abandon this class of traffic absolutely, but this is not altogether possible because serious obstacles must be overcome. For instance, all the less-than-carload freight to and from all local stations within a 25 to 30-mile zone does not originate or terminate within the zone, but comes from, or is destined for, points farther distant, and no way seems to be open at present to avoid maintaining service for this traffic.

Moreover, until the public mind is enlightened further there will be difficulty and, perhaps, ill-feeling will be engendered, if the rail carriers should attempt to close absolutely their local stations in the suburban districts to less-than-carload freight. It is necessary, therefore, to continue the service, but at the same time to benefit by any economies that may be secured through utilizing motor trucks.

This brought out the experiment that the Pennsylvania Railroad System is now undertaking at numerous points, as an illustration of which I shall refer to the main line of the Pennsylvania Railroad from Philadelphia to Downingtown, Pa., a distance of 32 miles, on a four-track railroad. In this territory considerable small-lot freight had already gone to local motor trucks, and the railroad was still maintaining the same plant for handling a considerably diminished volume of such business.

Instead, therefore, of the way-freight trains loading and unloading this less-than-carload freight at each of the 27 stations between the points mentioned, a plan was put into operation of loading less-than-carload freight from the city stations, or from distant points, into "destination" cars, after four important points had been selected as the destination stations, and distributing and picking up less-than-carload freight to and from the intermediate stations by motor trucks operating between these larger stations. Of course, westbound stations were selected that were different from those selected for eastbound traffic, because on a four-track railroad it is necessary always to have the stations on the side of the railroad that is served by the track running in the direction of the traffic. The results of the experiment, so far as we have been able to determine them after a comparatively short trial, have been

(1) The elimination of the local way-freight train, with a saving of the out-of-pocket cost for its operation, as well as the interference with other rail movements over that part of the division
(2) The substitution of a more adjustable factor of transportation, with an immediate moderate saving referred to above
(3) A reduced number of handlings of the freight and a consequent saving from loss and damage
(4) A more prompt and satisfactory movement of the less-than-carload traffic

The above plan involves no change whatever in the matter of dealing with the public in the transportation of this class of traffic, as the freight is brought to the freight station just as it has always been brought and is receipted for on the railroad company's bill-of-lading and under current freight-rates, the only change being the utilization, by contract with a motor truck carrier, of that form of transportation instead of the more unwieldy and less adjustable way-freight train. This experiment is being conducted in several districts on our railroad where relief is most needed, and undoubtedly it will be extended if it proves practicable and economical.

It is hoped that the trucking company will gradually secure all this less-than-carload freight for its own service, the whole way through from the shipper to the consignee. As the railroads are further relieved from this particular class of traffic, it should be possible to reduce the number of stations and, perhaps, through some arrangement for handling the long-haul less-than-carload traffic, to enable them to abandon entirely the short-haul small-lot freight to the more economical motor-vehicle. For, certainly, the railroad should not be expected to maintain its full plant for use when the motor truck fails, or when the weather is bad, but should be allowed to economize for the loss of such traffic by yielding the "field" and saving the expense of the plant that is now devoted to this particular traffic.

The Motorization of Terminals

Anyone familiar with railroad transportation methods knows that in the larger cities freight stations have been distributed at various points throughout the business districts in an effort to locate them advantageously for procuring competitive traffic and that, consequently, to serve all the various freight stations, it is necessary to duplicate the number of cars forwarded to and from a city so that its freight stations can be represented; or frequently to gather up freight from the stations and move it to a transfer-point located conveniently adjacent to the city, where the freight would be rehandled and reloaded into the through cars. In other words, much movement in and around the terminals is required after the cars have reached the receiving yard, inbound, or before they can be dispatched from the forwarding yard, outbound.

For instance, to serve 37 stations in Philadelphia that handle less-than-carload traffic, we estimate that 500 cars a day are moved between the yards that constitute the end or the beginning of freight-train runs and the stations referred to. It would seem desirable, therefore, to have all less-than-carload freight destined for Philadelphia, for example, unloaded at one properly constructed station in the immediate proximity of the receiving yard and distributed from that point by motor truck to the various stations located throughout the business districts; and, vice versa, to pick up all the less-than-carload freight from these stations by motor truck and haul it to the large station first referred to, for outbound loading.

This plan would seem to offer the following advantages:

(1) All inbound less-than-carload traffic to Philadelphia could be loaded for one station and not divided up into numerous cars for separate stations, nor transferred from one car to another at the terminal transfer-point
(2) All outbound less-than-carload traffic could be consolidated at one point and loaded for group destinations, thus making possible heavier loading and more through loading than is possible where a number of stations are performing the same function

(3) A saving in the use of cars for moving less-than-carload traffic between the outlying yards and the downtown stations
(4) Relief of the terminals in avoiding the car movement referred to, which will greatly expand the life of the terminals and inure to the benefit of the traffic
(5) Regularity of service, as all the outbound less-than-carload traffic would be forwarded the same day from one station and the inbound traffic would save the time of terminal movement

This development, however, means the construction of proper facilities for putting such a plan into operation, which, in a territory already highly developed through years of adjustment and extension of track facilities, is a very serious problem and involves a large initial outlay, so that it has been impracticable to make a definite start on such a program; but a serious study is being made, and it is hoped that decided progress can be reported soon along the lines indicated.

Here, again, the method of doing business between the trader and the railroad company is not changed in any way, but the plan involves merely the substituting of one method of distribution, the motor truck, for that of the carrier by rail.

Door-to-Door Delivery Service

It requires no argument to demonstrate that the customary method of delivering less-than-carload freight today, by having it unloaded at the freight station, sending notice to the consignee and allowing 2-days' free time for its removal, is uneconomical and requires an entirely disproportionate amount of platform space, which, in large business districts, means extremely heavy overhead expense; and, as reported by the Transportation Conference, the prompt delivering of this traffic to the consignee immediately upon its arrival would not only save a considerable amount of threatened expense for improved stations, but would indefinitely prolong the adequacy of the existing stations and greatly improve the service.

It is believed, therefore, that the railroad can be combined with the motor truck in performing a rail and motor less-than-carload freight service from the door of the shipper to the door of the consignee, very much as express traffic is handled at the present time, except that the rail-and-motor traffic would be handled on freight trains instead of on passenger trains.

The railroad students of this problem believe that such a service should be undertaken by a separate company and not by the railroad itself. This separate company would contract with the traders and be responsible for the transportation, simply utilizing the rail carrier from station to station under a proper contract. Such a rail-and-motor line would have to be a common carrier and assume all the duties and responsibilities of such a carrier under the law as to the filing of its charges, maintaining reliable service and being responsible for loss or damage and the like; it is the various complications of this necessity that have delayed the carriers in forming such alliances.

Furthermore, this service could not be forced upon the public but would have to be "sold" to it. Careful study, however, has convinced those interested that a real need would be supplied and that the utilization of the service by the shipping public would quickly follow to a material extent, because

(1) Under such a plan, the less-than-carload freight would be loaded on and unloaded from railroad cars at outlying stations, it being immaterial to the trader where the freight was loaded and unloaded so long as it was collected from and delivered to his door; and the adjustment of the drayage service would be a matter between the railroad and the rail-and-motor line in the division of the charges
(2) Freight stations would be relieved from keeping this traffic for the 2 days of free time and, indeed, be relieved from handling it over the congested platforms of the downtown stations
(3) The traders would be relieved from arranging for drayage after receiving the notice, and the shipper could have the freight delivered to the consignee under one transaction with the rail-and-motor line
(4) The charge would be reasonable, approximating the freight rate plus the customary drayage charge at either end, which would be much lower than the express charge for the same movement
(5) It is believed that loss or damage would be largely reduced through less exposure of the freight on the platforms

This final plan of coordination does, of course, create a new agency with the trader and must be undertaken in an experimental way with the hope that its usefulness will be proved and its utilization expanded.

Let me say a word here that may prevent some question from arising in your minds: Plan No. 2 for the Motorization of Terminals and Plan No. 3 for the Door-to-Door Delivery Service should not, in my judgment, be tied together, although others differ with me on this point.

It seems natural to say, if freight is put on a motor truck to be moved to a terminal, why should it be unloaded there rather than moved all the way to the receiver's door? But, after very careful thought, I am convinced that this mixes the railroad's part of the transportation, that is, from station to station by rail, with that of the consignee, that is, from the station to the door of delivery; and that plans Nos. 2 and 3 can never be worked together with real satisfaction, but the door-to-door delivery service should, as stated above, be undertaken by an organization entirely separate from that of the railroad, although utilizing the same company for actually performing the transportation.

The whole subject, I think, can be summed up as follows:

(1) Determine the "field" of the motor vehicle, and require the motor vehicle to assume all the responsibilities that go with the privileges it enjoys
(2) Coordinate rail transportation, electric-line transportation and motor-truck transportation, each serving its particular field and avoiding the competition of one field with another, a competition that never really benefits the public but is wasteful and in the end is expensive to the users of transportation

Vol. XIV March, 1924 No. 3

That Mind of Yours

By M. L. Burton[1] Annual Dinner Address

I HAVE deliberately chosen a subject full of mysteries which recent scientific investigations have only deepened and not solved. Let us concede at once that the mind is a baffling affair about which much is still to be learned. Even so, I have selected as the subject of our thought, That Mind of Yours.

The Primacy of the Mind

Little time need be spent in discussing the primacy of the mind. Its importance to us as individuals and to the social order is measureless. Knowledge is power. Your personal success in life will depend largely upon the quality of your mind.

While we hear it often, it cannot be said too frequently that intelligence is necessary for this American democracy. Under other forms of government it may be possible to endure ignorance, illiteracy and intellectual incompetence, but if America is to realize upon her invested hopes and aspirations we simply must proceed upon the expectation that we can have citizens well-informed and capable of reasoning upon the problems of community and national life.

All progress waits upon mental advancement and scientific attainment. The developments of the last three centuries have come because men with minds have sensed and solved some of the problems confronting mankind. There is no possible escape from the conclusion that if our generation expects to do its share in mastering the world and freeing men of every type of bondage, it must realize its aim through mental accomplishment.

Moreover, unprecedented problems await solution. Science in the last century has dazzled the world by its discoveries and inventions. Similarly the problems of its social sciences and of the whole gigantic structure that we call civilization challenge our generation to do its duty.

Our subject therefore bears specifically upon our individual and collective tasks here and upon all those larger issues so fundamental to our Country and to mankind. We must accept, if we understand the meaning of history, the primacy of the mind.

Types of Mind

You cannot long fail to discover that there are various types of mind.

There is the man whose mind is a *tabula rasa.* The world may write upon it and with complete receptivity it takes the markings. Such a person is curiously credulous and accepts seriously and with little sense of proportion the absurd rumors that circulate everywhere. He rarely applies the tests of reason. The more unlikely the report is, the more eagerly he drinks it in. Sharply contrasted to him is the man with an independent mind. He too hears what the world endeavors to say. But he insists that a man must classify and interpret the impressions that present themselves. He does not follow the mob. He has a mind of his own.

There is another contrasting pair of types of mind. The conservative idealizes the fact. Whatever has been, is true. He stands for a sequacious dependable world. He believes that the experience of the race has expressed itself in solid truth which must not be cast aside lightly. He is liable to illustrate the "vain proud unteachableness" of our natures. He finds it difficult to change his mind even when adequate reasons demand a new point of view. He is offset by the radical who idealizes the future and overlooks the plain lessons of the past. He is liable to confuse terms and technical jargon with realities and abiding truth. In the past he has been too essential to progress.

You will find all about you those who possess, in the best sense of the term, critical minds. They seek only for the truth. Their one fear is error, their one desire the facts. They are wide open to truth, new or old, and know no bonds of mere external authority or conventional custom. Such minds are discriminating. They distinguish carefully between beliefs, opinions and knowledge. They think closely upon the real issue of every problem. They never hesitate to take a position of doubt. They realize that every thinking person doubts at times. Likewise they candidly concede that knowledge has its limits and are fearless and undisturbed in the presence of mystery.

Finally, there is the creative mind. Civilization and progress depend upon it. It is more than the mind that works. It works too but it is constructive. It has initiative and vision. It toils but it grows. It expresses itself both in new terms and in new comprehensions of the facts of the universe.

The Thinking Mind the Ideal Type

Is there an ideal type of mind for a citizen of today? Of the various types of which we have spoken, you may have already selected the one that you can idealize. Surely the ideal mind will not be satisfied with mechanical or utilitarian processes. It cannot be satisfied by being merely a "grind" or a "commercialist."

To be worthy of his name, a man must possess a *thinking mind.* "What is the hardest task in the world?" "To think," says Emerson. The ideal man insists upon thinking and thinking first for himself before finding out what others have thought.

If you are to be a thinking man, you will have to reckon with your prejudices. They constantly throw you out-of-balance. You will cling rigidly to opinions that benefit you personally. Sheer ignorance will cause you to oppose some tenable points of view. Just because you find yourself possessing certain ideas, you will cling to them rigidly. Worst of all, you will tend to ignore or to forget the truths and the facts with which you disagree. Thinking in spite of your prejudices is one of your hardest tasks.

If there is anything to which people are highly sensitive, it is popularity. The thinking mind and popularity present a real dilemma. A thing is not true because it is either popular or unpopular. You cannot take as your thinking-standard the casual commonly accepted opinion of the world. We have the terrible habit of imagining that whatever a great many people are saying is true. If you begin to think independently, you will have to forget the superficial question of popularity. It comes

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and goes so quickly that a man with a mind soon learns to take it for what it is worth. It will not be very popular in some quarters to have a good mind. The best thing to do is not to say much about it but to proceed to think for yourself, basing your judgment on the facts.

A real mind proceeds to think about problems. It hunts for them and glories in them. It questions everything but does not run off into the dark. If it finds a real question it insists upon the answer. John Stuart Mill said in his autobiography that he attributed all his success in intellectual work to the habit "of never abandoning a puzzle but again and again returning to it until it was cleared up."

The ideal mind is the thinking mind that reckons wisely with prejudices, popularity and problems.

Gaining the Mastery of Our Minds

How shall we master our minds? We must never forget the unity of personality. We cannot separate the mind from the body or the body from the mind. How they interact no one actually knows. Apparently modern psychology has demonstrated that there are unconscious layers or elements in the mind which influence or control our behavior more than those elements of which we are aware. Into these deeper phases of our subject we cannot go but he who is to master his mind must master his whole being.

Strength of character that demands a clean, healthy mind is essential. There is no space to point out the bearings upon the phase of our subject of physical and mental hygiene. The right amounts of food, exercise and sleep are essential to mental mastery.

If you value highly that mind of yours, you will not only set out to master it but you will take practical steps to ensure its efficiency. You will have a time budget. That budget will set limits to every type of mental expenditure. It will express your mental policies. It will provide a general fund that will provide some flexibility. It will take full account of the complexities of life and your responsibilities to it. It will actually compel you to be a surgeon. The diseased, unused harmful parts will have to be removed mercilessly.

Back of everything must be the general habit of mental application. Casual interest spells failure. Mental absenteeism will not produce results. Keep your eye on the ball and carry through. Whether you are listening, reading, working or talking, focus your attention upon the matter in hand.

Have the spacious mind. This generation cannot supply all its mental needs by limiting itself to books or formal courses of instruction. Not even a university can teach any one individual all he ought to know. The world abounds in supplementary opportunities for enriching your mental tastes and deepening your thought processes. You must be the master of that mind of yours.

In conclusion, it may be said that our subject calls for a new emphasis in life. Your mind is your most precious asset. It makes you largely what you are. What type of mind will you have? You will have the bodies of men and women. Are you to have the minds of children? Possess the thinking, creative mind of which you are the royal master. As a man thinketh in his heart, so is he.

CHRONICLE AND COMMENT

(Concluded from p. 266)

or to the use of wrong lubricants. In one factory a system of field reports is maintained very carefully, the information received being classified by an engineer in a manner that permits the designing and experimental divisions to make proper interpretation of complaints. In redesigning or in considering changes in a new series of cars an effort is made to take full advantage of information received from the field, as this is considered of predominant value in the eliminating of maintenance troubles. Indeed, it is stated that in this connection the results of research work are relatively "academic."

What Can Be Done?

It is acknowledged by the engineer that to a certain extent there is insufficient personal contact between him and the service-manager. On the other hand, it is stated emphatically that it would not be compatible with the duties of the chief engineer of a large organization to undertake to maintain systematic personal contact with service-stations throughout the Country; in fact, that the personal contact of the chief engineer with service-stations is no criterion for judgment as to service efficiency. By having service-men working constantly between the field and the home office it is possible for the engineer to be familiar with maintenance conditions and for the men in the field to be informed of improvements accomplished. Reports that are compiled monthly show whether conditions are improving or growing worse in various particulars. The engineering department of one company has submitted for its approval, before they are sent out, service letters formulated by the service department.

There is doubtless room for improvement in the conditions surrounding the all-important matter of car maintenance, but it is certain that much sincere effort is being made to furnish service-men the information necessary for maintaining cars properly. The engineer seeks valuable first-hand information from the service-manager through the medium of a letter or a personal visit. In a large sense improvement of conditions in general depends largely upon fair thinking and manly appreciation of the other fellow's problem.

Engines for Oil versus Oil for Engines

AT the February meeting of the Buffalo Section an interesting discussion took place regarding the frictional losses in automotive engines that are caused by the varying qualities of the lubricants used. L. H. Pomeroy cited some experiments conducted by him with a view to ascertaining the relation of the lubricant to the internal friction of the engine at various speeds. A. L. Clayden in reply stated that the function of the lubricant was apparently misunderstood by engineers and that more research on the subject would be made by the oil refiners if they were given more encouragement to do so by the engineers.

MECHANICAL FRICTION AS AFFECTED BY THE LUBRICANT

BY L. H. POMEROY[1]

VERY few data seem to be available on the frictional losses in automobile engines caused by the failure of the oil to perform its function as a lubricant. The researches of the Lubrication Inquiry Committee in England indicate that the friction of a flooded bearing is proportional to the speed of the engine, the area of the bearing and the viscosity of the lubricant and is independent of the pressure and of the materials of which the opposing surfaces are composed.

The principal sources of friction in an engine are the crankshaft, the camshaft and the connecting-rod bearings, which rotate; the pistons and the valves, which slide; and the auxiliaries, such as the generator, the pump and the distributor. Experiments by the author led to the conclusion that a variation in the viscosity of the lubricant can easily account for reduced mechanical efficiency and consequently for the increased consumption of gasoline, and that the friction-loss is proportional to the cubic capacity of the engine, whereas the brake mean effective pressure for the same horsepower is inversely proportional to the capacity. Tables are given showing the variation of the friction mean effective pressure at various speeds and at various temperatures of the water and the oil, the fuel consumption of the engine at part throttle and at varying oil and water temperatures and a method of calculating the reduction of the gasoline consumption, assuming a constant indicated thermal efficiency. The identity of the results, as determined from the friction curves and from actual tests are said to suggest that the thermal efficiency is affected but little by the water-jacket temperatures and that the saving on account of the thermostats and the radiator shutters is caused almost entirely by the reduction in the viscosity of the oil. Because of thermostatic control the water temperature rises very rapidly to 120 deg. fahr. in short runs and to about 170 deg. fahr. after 15 or 20 min., but the oil temperature, even for periods of 30 min. of city driving, does not rise more than 40 deg. fahr. above atmospheric temperature, and after prolonged fast driving the rise amounts to about 90 deg. fahr. On the assumption that the temperature-difference between the oil and the atmosphere is independent of the atmospheric temperature, it is shown that to obtain a mean oil and water temperature of 170 deg. fahr., the condition of maximum efficiency, with water at 170 deg. fahr., the atmospheric temperature must be about 80 deg. fahr. if the car is driven at approximately 40 m.p.h., while for ordinary city driving the conditions of maximum efficiency are not realized unless the atmospheric temperature is about 130 deg. fahr. The suggested use of thin oil might not avail because in winter very severe conditions of load and speed are frequently encountered and a slight difference in the viscosity might be of great importance.

In making a study of methods of keeping dirt out of an automobile-engine crankcase, it was found that certain oils that worked well under normal conditions became too viscous in cold weather. This was remedied by making the troughlike conduit of wire gauze through which the oil when sufficiently hot drops into the main body of oil in the oil-pan. The property of oiliness increases in importance as the bearing surfaces more nearly touch each other, and especially when the engine is starting from rest.

ONE of the objects of this paper is to call attention to the lamentable lack of information on the subject of the frictional losses in automobile engines that arise from the oil that is alleged to function as a lubricant. I can see no reason why engineers are not entitled to the same cooperation and technical assistance from the oil-maker that are so cheerfully rendered by makers of components, bearing, steel, aluminum, electrical equipment, and the like. Whether it is sheer indifference, lack of technical facilities, non-appreciation of the problem or what not, is obscure.

One can search the literature of lubrication in general and of the automobile in particular, yet obtain very few useful data on the mechanical efficiency of the automobile engine as affected by the oil itself. It seems to be tacitly assumed that the oil is a relatively constant and insignificant friction-producer and that the engineer should design his engine for the oil, instead of the oil-maker making his oil for the engine.

As things stand now, the intelligent designer has to do his humble best to side-track the manifold disabilities of the viscous compounds that in the present state of mechanical art he has to tolerate.

In saying this, I am by no means unmindful of the excellent work on the subject of lubrication that has gone on in America and England these last few years, particularly that recorded in our own TRANSACTIONS and that of the Lubrication Inquiry Committee in England. The problem as it has been studied, however, is analogous to determining what alcohol-content is necessary to cause intoxication as against what happens to the person intoxicated. The researches of the Lubrication Committee indicate that the friction of a flooded bearing is (*a*) proportional to the speed of the engine, (*b*) proportional to the area of the bearing, (*c*) independent of the pressure on the bearing, (*d*) proportional to the viscosity of the lubricant and (*e*) independent of the materials of which the opposing surfaces are composed.

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Causes of Mechanical Friction

Let us consider, very briefly, what causes mechanical friction in any given automobile engine, where the areas and the pressures are determined by the design, leaving the speed and the viscosity as variables.

There are, first, the friction arising from the crankshaft, the camshaft and the connecting-rod bearings, which rotate; secondly, that of the pistons and the valves, which slide; and thirdly, that of the auxiliaries, such as the generator, the pump and the distributor.

The first and the second of these are our immediate concern. The friction in the crankshaft, the camshaft and the connecting-rod bearings is, of course, of the well-known journal-friction type, differing, however, in that the loading and the direction of the loading are constantly changing. The second, piston friction, is interesting because it involves starting and stopping during each stroke, which may and probably do alter the character of the frictional resistance produced.

The experiments about to be described are an attempt to show roughly how the viscosity of the lubricant affects the internal friction of an automobile engine at various speeds. It will be shown that, in the case under discussion and by inference generally, the variation in the viscosity of the lubricant can easily account for a reduction in the mechanical efficiency and therefore an increase in the gasoline consumption under ordinary winter-running conditions, of some 35 per cent, which is no mean item.

The experiments were carried out on a six-cylinder, 3¼ x 5-in. L-head engine of conventional general design, except for the extended use of aluminum in its construction. The lubrication system is of the full-force type, including wristpins and camshaft bearings. The primary differences, insofar as lubrication and its effect upon mechanical efficiency are concerned, are threefold:

(1) The use of cast-iron sleeves inserted into an aluminum cylinder-block increases the temperature of the oil-film and to some extent accounts for the low friction-losses at full load

(2) The use of aluminum connecting-rods and the consequent increase in oil-film thickness at the higher temperatures of full-load running also contribute to low friction-losses

(3) The rapid warming-up of the engine after starting reduces the duration of the period of gross inefficiency. This is important when an automobile is driven less than 2 or 3 miles at a stretch

It should be pointed out that the term "friction-loss" is used above instead of mechanical efficiency. The reduction of the friction-loss is far more important thermally than is the increase of the mechanical efficiency at full load. These losses, like the poor, are always with us, whereas we seldom take advantage of the full power that an engine can exert.

Comparison of Two Engines

For example, comparing two engines of 250-cu. in. capacity at 1000 r.p.m., the first with a brake mean effective pressure of 96 lb. per sq. in. of piston-area and a friction-loss of 16 lb. per sq. in. of piston area, the second with 90 lb. per sq. in. of brake mean effective pressure and 15 lb. per sq. in. of friction mean effective pressure, both therefore having the same mechanical efficiency at full load: At the load appropriate to a car running at, say, 20 m.p.h., that is, a 250-cu. in. engine exerting a brake mean effective pressure of some 13 lb. per sq. in., the relative powers exerted are as 16 + 13 is to 15 + 13, or as 29 is to 28. The gasoline consumption is then as 28 is to 29, a difference of some 3½ per cent.

This illustrates the state of affairs when comparing two engines of the same size but of differing power and running at the same speed.

If, however, the comparison be extended to two engines of the same power but differing in size, the experiment is all in favor of the smaller engine. In this case, the friction-loss is proportional to the cubic capacity of the engines, while the brake mean effective pressure for the same horsepower is inversely proportional to the capacity.

It may be well to explain the term "friction mean effective pressure." During the last few years it has become a recognized method of criticism, when dealing with engine horsepower for various sizes of engine, to correlate them by referring to the mean effective pressure developed on the piston. In the working cycle, we have, of course, a negative pressure or suction during the inlet stroke and a positive pressure during the compression stroke, in each of which work is done upon the mixture; then the explosion stroke, when we take back at compound interest what we have lent during the compression stroke; and finally a positive pressure during the exhaust stroke when, having enfeebled our debtor all we can, we cast him into outer darkness. The average of all these pressures upon the piston is called the mean effective pressure.

During the process described above, we must, of course, overcome the internal friction of the engine. This necessitates work, and this work can be related to pressure per square inch of piston-area in the same way that the fluid pressures are related. We then have a means of comparing the friction of various engines regardless of their size, number of cylinders or aught else. Frictional losses can be reduced by rational design but, even so, the effect of oil viscosity decidedly swamps the engineer's best efforts, unless these include viscosity.

Table 1 shows the figures relating to a series of tests on the friction mean effective pressure at various speeds and different water and oil temperatures. These tests were carried out on a Sprague dynamometer, the temperature of the water being measured by thermometers some 6 ft. away from the cylinder outlet and that of the oil by a calibrated Boyce long-distance motometer inserted into the oil-pan a few inches from the pump suction. The ideal method of altering one variable at a time could not be followed, because of the lack af apparatus for definitely controlling the oil and the water temperatures.

Although the figures appear to be somewhat of catch-as-catch-can order, there are no rules of wrestling that apply to the reduction of data, provided that one does

TABLE 1—RESULTS OF FRICTION MEAN EFFECTIVE PRESSURE TESTS AT VARIOUS SPEEDS AND DIFFERENT OIL AND WATER TEMPERATURES

Friction Mean Effective Pressure, Lb. per Sq. In.	Temperatures, Deg. Fahr. Oil	Water
500 R.P.M.		
13.10	150	70
8.40	174	100
8.00	170	120
7.85	168	130
7.75	166	140
7.65	162	150
20.20	56	70
15.80	58	100
14.40	62	115
13.60	61	122
15.80	90	70
12.80	122	72
7.85	162	145
10.60	170	72
7.35	180	123

TABLE 1—RESULTS OF FRICTION MEAN EFFECTIVE PRESSURE TESTS AT VARIOUS SPEEDS AND DIFFERENT OIL AND WATER TEMPERATURES (*Concluded*)

1000 R.P.M.

Friction Mean Effective Pressure, Lb. per Sq. In.	Temperatures, Deg. Fahr. Oil	Water
13.4	163	82
10.8	171	108
10.5	170	122
10.4	167	135
10.2	165	140
9.9	162	142
10.2	161	145
13.2	176	75
10.3	179	127
24.6	57	71
20.2	58	102
19.5	62	117
18.9	64	122

1500 R.P.M.

Friction Mean Effective Pressure, Lb. per Sq. In.	Temperatures, Deg. Fahr. Oil	Water
15.5	169	85
13.5	169	110
12.5	170	125
12.3	167	135
12.1	165	140
12.3	162	142
12.3	161	145
13.3	180	78
12.1	179	129
12.2	174	150
23.7	57	75
22.0	58	105
21.2	62	118
20.9	64	120

2000 R.P.M.

Friction Mean Effective Pressure, Lb. per Sq. In.	Temperatures, Deg. Fahr. Oil	Water
17.70	174	95
16.65	170	115
16.00	170	130
16.10	167	137
15.90	165	141
15.60	163	145
15.80	161	145
17.90	182	85
14.80	180	130
14.70	174	150
27.20	57	80
24.20	60	105
23.40	62	118
23.00	66	120

2500 R.P.M.

Friction Mean Effective Pressure, Lb. per Sq. In.	Temperatures, Deg. Fahr. Oil	Water
20.6	182	97
19.6	179	137
19.5	175	152
29.7	58	87
28.2	62	112
26.6	66	120

3000 R.P.M.

Friction Mean Effective Pressure, Lb. per Sq. In.	Temperatures, Deg. Fahr. Oil	Water
29.0	182	115
29.0	179	142
36.6	58	109
33.4	62	112
35.0	64	122

not indulge in interpolation or extrapolation without reason. With regard to these figures, it will be noted at once how dependent the friction is upon the oil and the water temperatures.

Fig. 1 shows the friction mean effective pressure of various speeds in terms of the mean of the oil and the water temperatures. In view of the nature of the tests, these plot fairly well.

The overwhelming influence of oil viscosity indicated in all the tests would make it reasonable to assume that the fall in the friction with a rise of the temperature follows to some extent the viscosity curve of the lubricant itself. This curve is shown in Fig. 2. It will be readily seen that, for a given temperature-difference, the fall in the viscosity is vastly greater than the fall in the engine friction over the same temperature range.

It is suggested therefore that the actual oil-temperature in the bearings is very much higher than that indicated by temperature measurements in the oil-pan, so that an appropriate comparison, so far as the viscosity curve is concerned, would be on a part of the curve where the temperature is higher than in the oil-pan.

TABLE 2—FUEL CONSUMPTION AT PART THROTTLE AT 1000 R.P.M. AND VARYING OIL AND WATER TEMPERATURES

Power Developed, hp.	3.40	4.70	4.95
Brake Mean Effective Pressure, lb. per sq. in.	10.70	14.70	15.60
Indicated Mean Effective Pressure, lb. per sq. in.	31.70	31.20	29.80
Mean Temperature of Oil and Water, deg. fahr.	100	128	152
Fuel Consumption, lb. per b.hp-hr.	1.950	1.360	1.280
Fuel Consumption, lb. per i.hp-hr.	0.655	0.640	0.670

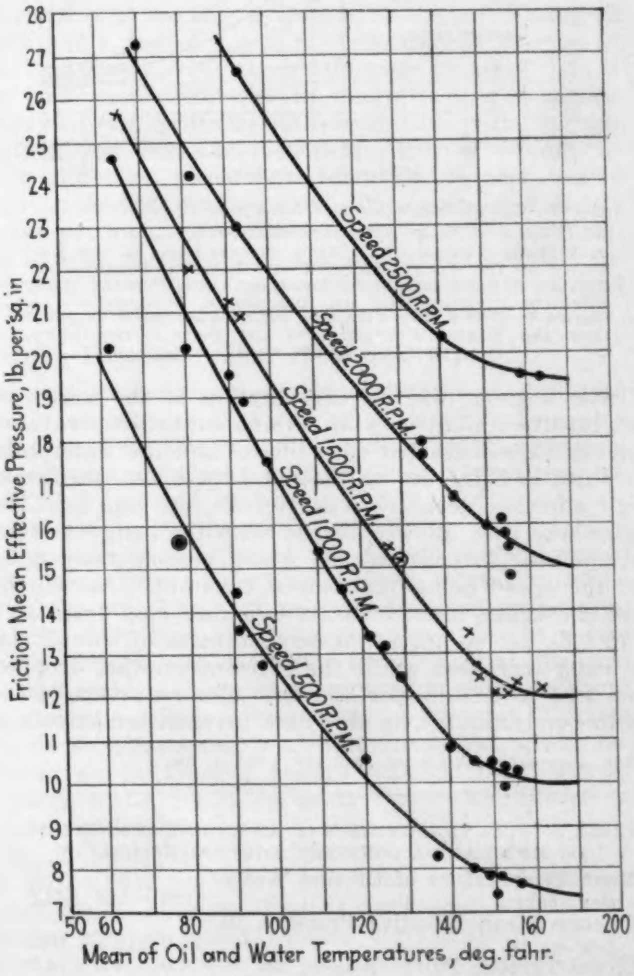

FIG. 1—CURVES OF THE FRICTION MEAN EFFECTIVE PRESSURE AT VARIOUS SPEEDS IN TERMS OF THE MEAN OF THE OIL AND WATER TEMPERATURES

These Curves Give the Results of a Series of Tests, the Figures for Which Are Presented in Table 1

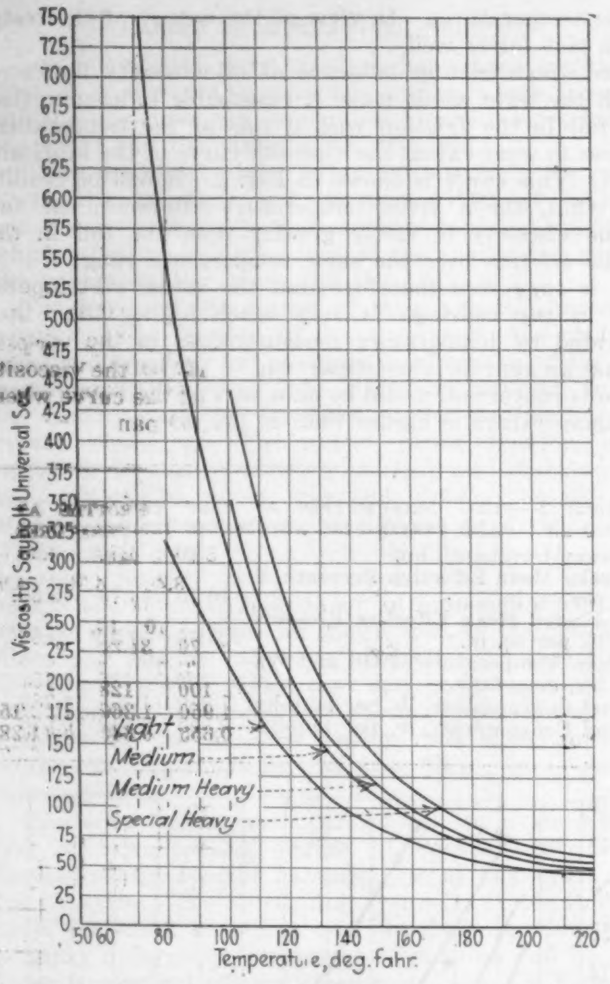

FIG. 2—CURVES SHOWING THE RELATION OF THE VISCOSITY TO THE TEMPERATURE

It Will Be Noticed That While the Decrease in the Viscosity of the Four Oils with the Rise in Temperature Follows to Some Extent the Decrease in the Friction Mean Effective Pressure with an Increase in Temperature as Shown in Fig. 1, the Viscosity Falls Much More Rapidly than the Engine Friction over the Same Temperature Range

Table 2 gives the fuel consumption of the engine at part throttle and at varying oil and water temperatures. The engine was started with the oil and the water cold, the throttle being set so that at 1000 r.p.m. the brake mean effective pressure was 10.7 lb. per sq. in. The engine was then allowed to run with the same throttle-setting until the oil and the water became thoroughly hot, the speed being maintained constant. As will be seen, the brake mean effective pressure rose from 10.7 to 15.6 lb. per sq. in. as the temperatures of the oil and the water increased, while the fuel consumption dropped from 1.95 to 1.28 lb. per b.hp-hr. The reduction in the gasoline-consumption, in this case between temperatures of 100 and 152 deg. fahr., is 0.67 lb. per b.hp-hr., or some 34.4 per cent.

Upon the assumption of a constant indicated thermal efficiency, the reduction in gasoline-consumption may be calculated from Fig. 1. The results are given in Table 3.

On this basis, the improvement in gasoline-consumption is (52.5 — 34.0)/52.5 = 35.2 per cent, a figure in good accordance with the experimental result. The closed-throttle pumping-loss, or the difference in the friction at closed and at open throttle, is that measured in the tests. It will be seen that the indicated mean effective pressure, computed from Fig. 1, falls from 31.7 to 29.8 lb. per sq. in. This may be caused either by errors in the readings of friction or by the reduced volumetric efficiency as the engine warmed-up during the test, probably the latter.

The substantial identity of the results, as determined from the friction curves and from actual tests, suggests that the thermal efficiency is affected but little by the water-jacket temperatures and that the saving on account of the thermostats and radiator shutters is caused almost entirely by the reduction in the oil viscosity. This is confirmed by calculating the fuel-consumption, which at 100, 128 and 152 deg. fahr. is 0.65, 0.64 and 0.67 lb. per b.hp-hr. respectively.

To round off this matter, the temperature observations taken on my car during the month of January are presented in Table 4. They are probably typical of the average hack use of an automobile, and indicate under what extraordinarily bad conditions of mechanical efficiency the ordinary automobile engine is required to function.

It will be seen that, because of thermostatic control, the water temperature rises very rapidly to 120 deg. fahr. in short runs and to about 170 deg. fahr. after 15 or 20 min. On the other hand, the oil temperature, even for periods of 30 min. or so of city driving, does not rise more than 40 or 50 deg. fahr. above atmospheric temperature, but after prolonged fast driving it rises about 90 deg. fahr. above atmospheric temperature. This figure compares with a temperature-rise of 60 deg. above atmospheric temperature in the oil-pan of omnibus engines, as given in H. D. Nickinson's paper read before the Institution of Automobile Engineers in December, 1923.[2]

On the assumption that the temperature-difference between the oil and the atmosphere is independent of the atmospheric temperature, it will be seen that to obtain a mean oil and water temperature of 170 deg. fahr., the condition of maximium efficiency, with water at 170 deg. fahr., the atmospheric temperature need be some 80 deg. fahr. if the car is driven really fast, that is, averaging some 40 m.p.h., while for ordinary city driving the conditions of maximum efficiency are not realized unless the atmospheric temperature is some 130 deg. fahr.

Stated in another way, the readings show that during the month of January, 1924, with atmospheric temperatures between 12 and 42 deg. fahr., the corresponding mean oil and water temperatures are about 80 to 105 deg. fahr. for short runs of some 8 min. duration, and 112 to 130 deg. fahr. for runs of approximately 1 hr., under "all-out" conditions. Reference to Fig. 1 shows that these mean temperatures are a long way below the optimum.

Thanks to the fortunate discovery of an honest log of gasoline-consumption and mileage on the part of Mr. Davies of the Aluminum Co. of America, an interesting check is obtainable on the foregoing arguments. This

[2] See *Automobile Engineer*, January, 1924, p. 24.

TABLE 3—FUEL CONSUMPTION OF AN ENGINE RUNNING AT 1000 R.P.M. AND A CONSTANT THERMAL EFFICIENCY

Mean Temperature of Oil and Water, deg. fahr.	100	128	152
Friction Mean Effective Pressure, lb. per sq. in.	17.0	12.5	10.2
Closed-Throttle Pumping-Loss, hp.	4.0	4.0	4.0
Brake Mean Effective Pressure, lb. per sq. in.	10.7	14.7	15.6
Indicated Mean Effective Pressure, lb. per sq. in.	31.7	31.2	29.8
Mechanical Efficiency, per cent	34.0	47.0	52.5

TABLE 4—TEMPERATURES OBSERVED ON AN AUTOMOBILE ENGINE IN JANUARY

Date	Distance, Miles	Time, Min.	Temperatures, Deg. Fahr.						
			Oil		Water		Atmospheric	Mean of Oil and Water	Difference between Mean of Oil and Water and Atmospheric
			Initial	Final	Initial	Final			
5	1.8	8	40	40	45	120	12	80	68
	1.8	10	40	42	50	120	....	81	69
	11.7	95	40	70	50	155	....	112	100
	4.6	50	40	60	70	140	....	85	73
6	1.8	8	30	45	45	120	32	82	50
	1.8	8	45	55	45	110	....	82	50
7	4.3	25	35	65	45	165	26	115	89
	2.8	12	35	47	12	120	....	83	57
	2.8	11	35	52	70	130	....	91	65
8	1.8	8	45	60	70	120	38	90	52
	18.1	60	45	105	80	150	....	128	90
10	2.7	20	50	70	50	140	42	105	68
11	1.8	8	60	65	55	145	40	105	65
	22.1	60	60	100	40	150	34	125	90
12	23.4	....	50	100	50	140	....	125	90
	37.0	60	100	120	140	140	22	130	108
	1.8	8	40	50	40	130	28	90	62
14	9.0	55	50	85	95	145	....	115	....

log shows that in consuming 434 gal. of gasoline between July 11 and Nov. 10, 1923, a mileage of 13.1 per gal. was obtained, while a consumption of 267 gal. of gasoline between Nov. 10, 1923, and Jan. 30, 1924, only produced 9.8 miles per gal. The hot-weather consumption in this case is thus 33.8 per cent better than that obtained in cold weather.

Gasoline Consumption Reduced

Summing up, we have, as between an engine working under cold and hot conditions, that is, over a mean oil and water temperature range of 100 to 150 deg. fahr., a reduction of 34.4 per cent in the gasoline consumption, as obtained from test-bench experiments under load, a reduction of 35.2 per cent indicated by friction measurements and, in the case of the actual operation of an automobile, a reduction of 33.8 per cent. It is freely granted that these are only isolated examples; nevertheless they bear an uncanny relation to one another and should not be dismissed without comment.

The obvious retort from the oil-maker would be that thin oil should be used in winter. Unfortunately, even in winter, conditions may arise, such as those of pulling out of a snow-drift, in which the most extreme conditions of engine load and speed are encountered. There seems to be a not unnatural belief that, in such a case, the use of a light oil would entail the risk of bearing failures. This belief is strengthened when the relative viscosity curves of different oils are considered. Although oils of very different viscosity at low temperatures tend toward a common viscosity, as shown in Fig. 2, if the temperature is sufficiently increased, there seems to be a considerable difference in viscosity inside the normal temperature-range of an automobile engine. Data upon the loading that can be utilized in a bearing seem sadly lacking. All that seems to be known is that the friction is independent of the load, but this only applies to a flooded bearing and it is easily conceivable that a bearing ceases to be flooded when the oil gets very thin and a partial metallic contact begins to take place.

When this is so, the difference in viscosity between a thick and a thin oil at high temperatures may be of great importance even though it may be small. In a word, this small difference in viscosity is appropriate to a very large increase in the temperature of the heavier oil, since the viscosity-temperature curves of oils of greatly differing viscosity when cold become nearly parallel to the temperature axis. The engineer is, therefore, and not for the first time, on the horns of a dilemma. If he is working for a high efficiency under normal conditions, he is running risks at high temperatures, and vice versa. Now as to what can be done about it.

Excluding Dirt from Crankcase

About 2 years ago an opportunity arose to study the question of keeping dirt out of an automobile-engine crankcase. Few things could be more instructive than to note the multitude of microscopic apertures through which road grit and dust could and did enter, not only as single spies but in whole battalions. The problem then became one of reducing the ingress of the dirt and at the same time preventing it from getting into the lubricating oil. The first was accomplished by bottling up tight every part of the engine, such as the valves and the springs, and the latter by my partial filtration method, by which a very effective filter is placed in shunt with the main oiling system so that very good filtration proceeds simultaneously with the circulation of the oil. In other words, there is always sufficient oil to supply the pump while the oil is being thoroughly filtered at a fairly rapid rate.

The adoption of this scheme worked excellently on cars used under conditions of normal and fast touring. It was found, however, that in very cold weather the oil-pump suction would become starved owing to the lubricant's being about as viscous as an asphalt pavement on a hot day. To remedy this, the oil-filter tray was arranged so that the oil deposited on it during the first few minutes of running was gently encouraged to repeat its performance as a lubricant by being conducted

along a trough-like conduit of liberal area to the pump suction. This worked perfectly and no trouble arose with the whole device until recently when during some intensive testing a big-end melted-out. This was a matter of much concern, for big-ends have no business melting-out nowadays.

Investigation showed that the conduit referred to was leading extremely hot oil direct to the oil-pump suction, so that the engine was being lubricated with oil at a temperature of probably from 350 to 400 deg. fahr. The cure was obvious, though I hope patentable, namely, making the conduit to the pump suction of wire gauze. This allows for the necessary safe conduct of very cold oil direct to the pump suction. After this gets reasonably hot, it drops through the gauze into the whole body of oil in the oil-pan. This device appears to have in it the possibility of a fairly definite control of viscosity. What is wanted, of course, is an oil that is fluid at low temperatures and fairly viscous at high temperatures, and the above device aids somewhat toward the desired end.

The question of lubrication and oil viscosity is more far-reaching than it looks. It is easily conceivable that in the not very distant future engines will be known by the lubricants they have to use, that the high-class well-made job will use a thin oil with all that this means in reduced gasoline-consumption and increased power, to say nothing of easy starting, while mediocre and cheap engines, in which the exigencies of rapid production impose as wide a bearing tolerance as is permissible, will use heavy oil on the grounds of silence and general reliability. If so, the purchaser of a cheap car will pay a heavy interest on his purchase price in the shape of gasoline and oil consumption, as compared with the purchaser who can make a larger initial outlay.

The Question of Oiliness

I have said nothing about oiliness, though I appreciate its importance, since it appears that it will not be of primary importance until our bearing surfaces more nearly touch than they do now. Oiliness seems to be more important in starting from rest and, apart from the piston, the motions of an engine are continuous. In the case of the piston, however, it may well be that the newer oils are important. To the automobile engineer, it will be clear that, in the absence of something new in oils with a constant viscosity-temperature curve, the question of oil-temperature control is worth some thought.

At the moment, there is great interest in the subject of gasoline economy, not perhaps so much for what it is as for what it means in the improvements that are bringing it about. It is the public's rough measure of a host of other related improvements. This being so, it is worth encouraging, as our business is not so much to make for one dollar what any fool can make for two as to make for one dollar something that any fool can sell for two.

There are three main lines of development toward this end:

(1) Improvements in the engine cycle itself, among which are the use of doped fuel and high compression, stratification engines and the like
(2) Weight reduction
(3) Improvements in mechanical efficiency

I trust that this paper may be considered as a contribution to the third of these.

The reasons that improvement in gasoline-consumption friction experiments is not related to carburetion are

(1) At high manifold vacuum vaporization is relatively easy to obtain at a mean temperature of 100 deg. fahr.
(2) No loading occurred in the inlet-manifold
(3) Vaporization would certainly have been complete at the end of the compression stroke owing to the large dilution at part throttle, that is, the small charge and the large proportion of hot exhaust-gas
(4) Fuel consumption per indicated horsepower-hour

THE FUNCTION OF LUBRICANTS

BY A. L. CLAYDEN[3]

IN engine design the fact that the engine must be lubricated is apparently overlooked. Few engineers realize the difficulty of doing it properly. With proper lubrication the life of the average engine would be doubled and probably quadrupled, because under the usual conditions the engine is lubricated only a part of the time. The function of the lubricant is not to take the place of cast iron, to make an octagonal bearing round, or to force its way to the right spot against resistance. Too great stress is laid on design; when cylinders are round and piston-rings fit perfectly, the amount of dilution is negligible, unless the manifold system is below the average.

The function of oil is to provide a film upon which the piston and piston-rings may slide, not to prevent the escape of expanding gases by blocking up the cracks in the cylinder. Too much time is devoted to the design of trick piston-rings when better results could be obtained by producing accurate cylinders. It is the rule, rather than the exception, to find 25 per cent of solid matter in crankcase drainings.

Tractor engineers have learned that the life of cylinders and pistons can be measured in hours if the breathing-in of abrasives is not prevented. Several methods of accomplishing this have been tried: (*a*) by providing an oil-screen around the pump that will admit oil but exclude foreign matter, (*b*) by using a fine-mesh screen, not fine enough to exclude fine dust but fine enough to clog and prevent the flow of cold oil and (*c*) by using a fine screen but assuming that although it would clog, enough oil would force its way through to furnish the requisite percentage for use. Most engineers seem to assume that if oil is put into the engine it will find its way to the proper place somehow. Today attention is being paid to providing ample lubrication, but not enough attention is paid to the condition of the oil. Oil refiners would make more accessible the meager amount of information on lubrication that is available if they were given proper encouragement by engineers, researches on lubrication being usually looked on as purely academic and of no practical value.

Thermostatic control was formerly more important than it is at present with modern types of manifold. It is valuable principally in heating oil in cold weather and cooling it in warm weather. In addition to being difficult to construct, oil-coolers usually have the effect of chilling the film in direct contact with the surface and interfering seriously with the cooling efficiency of the radiator. A comparatively heavy oil intended to

[3] M.S.A.E.—Chief engineer of gas engine research, Sun Oil Co., Philadelphia.

be operated warm accumulates less fuel than a comparatively thin oil intended to be operated cool. Manufacturers' instructions usually consist of the statement that the oil should be changed after a definite mileage. The two objections to this are that the instructions generally are not followed, and that draining rarely removes more than one-half the accumulated solids from the oil-pan.

OIL is a necessary evil, and the attitude of most engineers toward it is rather like that of the average man toward Monday morning. We cannot avoid it, yet hate to think about it. Though I think I have never known anybody who really enjoyed Monday mornings, there are a few who mind them less than others, mainly, I think, those who can remember early on Sunday evening that Monday is ahead of them. Similarly with engine design; if a little previous consideration is given to the fact that the engine must be lubricated, the difficulty of doing it efficiently will be very much reduced. A thought that engineers realize in only the very rarest instances is, what a complicated job the thorough lubrication of an engine really is. It is no exaggeration to say that, given proper lubrication, the life of the average automobile engine could be doubled and probably quadrupled. This is because the average engine is constructed so that it is lubricated with oil for only a very short part of its life, possibly 5 per cent, certainly not more. For the rest of the time it is given a mixture of fuel, coke, sand and cast-iron powder, with a modicum of oil to bind the whole together into a nice grinding-paste.

Then, again, some engineers have strange ideas as to the function of a lubricant. In the majority of present-day engines, and when I say majority I mean it, the principal function of oil is to take the place of cast iron that is not there. It is possible to produce oil with very remarkable properties, but I have yet to see a lubricant combining the Brinell hardness of good cast iron with the fluidity of kerosene. This is really what is required when an oil is asked to make an octagonal cylinder operate as if it were round, and at the same time find its way into the bearings by the happy accident of falling upon them at the right spot, especially when the bearings are so grooved that they automatically reject any molecules of oil sufficiently persistent to burrow their way in.

Leakage in an Automobile Engine

It is a sort of fetish found, I think, at its worst in the production side of our factories, that the important thing in an engine is its design. I do not need to say much about oil dilution, except to insist again that it is not a lubrication question; it is to a very limited extent affected by the engine design; it is almost entirely controlled by the builder. If engine cylinders are round within 0.0005 in. when they are both hot and cold, when the piston-rings fit perfectly against the cylinders and in the piston grooves, then dilution will be so slight that it can be almost forgotten, unless the manifold system is far below the average. On the other hand, with the ordinary kind of pistons and cylinders severe dilution will occur, however good the manifold design may be. The function of oil in an engine is to provide a film upon which the piston and piston-rings can slide. That is lubrication. It is not the function of oil to block up cracks and slits to prevent the escape of expanding gases. That is calking. I should like to ask if any of the engineers present are aware of the volume of leakage permitted in the average automobile engine. I do not propose to quote figures, but merely to suggest that those who do not know the extent of this leakage will probably be greatly astonished if they will take the trouble to investigate. Here again let me remark, as another strange example of engineering psychology, the fact that much more thought seems to be given to the construction of trick piston-rings intended to overcome the polyhedral irregularities of so-called cylinders than to the construction of cylinders accurate enough to be mathematically worthy of their name. I suppose the majority of human beings find it impossible to overcome the fundamental hope that some formula exists for making silk purses out of sows' ears, if only they could discover it.

Overcoming the Dirt Evil

If any of you were buying oil at a filling-station and the attendant were to fill his measure and then, just previously to emptying it into the engine, were to stoop down and gather up a handfull of road dust and throw it into the oil, I doubt if your remarks would be entirely suitable as a bedtime story. Yet the chances are that oil so treated would be no worse than the lubricating liquid already in the engine. Do you know that it is the rule, rather than the exception, to find in crankcase drainings 25 per cent of solid matter? The usual question in response to this announcement is, "How does the dirt get there?" to which the reply is, "What is there to stop it?" An engine aspirates many cubic feet of dust-laden air in every second that it is running. Most of this dust is non-combustible and much of it is carried through to the crankcase by the piston leakage already mentioned; still more of it is deposited in the oil-film to be caught and worked-in by the ascending piston.

Tractor engineers discovered very quickly that the life of cylinders and pistons could be measured in hours if something were not done to stop this breathing-in of abrasives, but until very recently the automobile industry has wholly failed to profit by this example. Today attempts to overcome this dirt evil are being made along two lines. First, prevention of its ever entering the engine and, secondly, its removal from the oil as soon as possible after its absorption. It is no part of the lubrication man's business to comment upon the air-cleaner, except to say that if a 100-per cent-effective air-cleaner could be adapted to automobiles, it would be very greatly to their advantage. It is, however, strictly the lubrication man's business to hold opinions upon methods of removing foreign matter already in the oil. Here we have seen two common practices. One has been to provide an oil-screen of large enough measure around the pump to allow liquids and fine solids to pass but small enough to exclude connecting-rod bolts, bits of piston-rings, lumps of babbitt and similar bodies, whose presence in the crankcase is probable when lubrication is attempted with a mixture consisting of oil, residual matter and fuel in approximately equal proportions. The other scheme is a fine-mesh screen, not fine enough to exclude fine dust but fine enough to prevent completely the flow of cold oil and fine enough so that it clogs very readily. Which of these two schemes is worse it would be very hard to say.

Another method of screening that met with considerable favor some years ago is to cover the whole oil-pan with a fine screen, the theory being that while the screen will admittedly clog very easily, its area is so great that the flow through it will be sufficient so long as a comparatively small percentage is not clogged. The effect of this was that in cold weather, immediately upon start-

ing, all the oil would be pumped out of the sump and would lie on top of the screen until such time as it had been warmed-up enough to flow through the minute orifices in the screen. These screening schemes seem to show very clearly how utterly the engineer has failed to grasp the nature of the problem. The most casual examination of used oil from a crankcase will make clear the utter impossibility of removing the solids by any conceivable system of wire-mesh screening that can be accommodated within the crankcase and still permit circulation through it of all the oil in the system at every circuit.

I shall never forget a meeting held 18 years ago in the Royal Automobile Club in London, at which the subject of lubrication was discussed. Somebody asked, "How is it that the wristpin ever receives any oil at all?" A gentleman remarked that in his early youth his mother's principal concern had been "how molasses got into his hair." He said, "It always did." He assumed that "oil reached the piston-ring in much the same way." Until recently, the majority of engineers seemed to assume that if they put oil into the engine it would somehow get to the place that needed it. Today they are taking considerable trouble to distribute oil to the places where it is needed, but are paying almost no attention to the condition of the fluid itself.

Cooperation Between Refiners and Designers Necessary

In the beginning of his paper Mr. Pomeroy stated that he has had great difficulty in obtaining answers to lubrication questions of a fundamental nature. The real explanation of this is that the questions are hardly ever asked. The literature on lubrication is somewhat meager, but none the less much is known. Oil-refiners would undoubtedly see to it that considerable existing information was put into more readily usable forms if they received a little encouragement from the engineering profession. It is curious but nevertheless a fact that an automobile engineer will take some fuel-research work done in a reputable laboratory as being worthy of real study, while he will look upon an equally important research on lubrication as being purely academic and of no practical value. Not long ago the thermostatic control of water temperature was very important from the carburetion viewpoint; with modern manifolds it is much less important. Mr. Pomeroy brings out very clearly the really substantial advantages that could be derived from the thermostatic control of oil temperature. Such control could consist of arranging either to heat oil in cold weather, or to cool it under summer conditions, or possibly a combination of the two. Oil-coolers are difficult things to construct. When anything like an ordinary radiator is used, the effect on the hot oil is to chill the film in direct contact with the surface that by its high viscosity and poor conductivity interferes very seriously with the cooling efficiency of a radiator. Heating it, on the other hand, is much easier to accomplish. The use of a comparatively heavy oil intended to be operated warm as compared with a comparatively thin oil intended to be operated cool, is that the accumulation of fuel will be less rapid in the former case.

A great many data from the oil industry are already available to the automobile engineer for improving the efficiency of engines and the industry is ready to finance and conduct much more research, but as yet very little indication that automobile builders have the least interest in the subject has been noticed. The oil industry is now asked to produce lubricants that will work equally well hot or cold, pure or diluted, clean or dirty. The first step is to produce engines that do not contaminate the oil with other fluids or solids. When this desirable stage of development has been reached, it will probably be possible to obtain enough public interest so that the lines of real research that Mr. Pomeroy states may be followed. Every manufacturer's instruction-book attempts to dodge this question, stating merely that oil should be changed at some definite mileage. There are two objections to this method of dealing with the subject, the first being that the user does not obey the instructions. It would be very surprising if he did, considering that more than 99 per cent of the engines are designed so that it is impossible to drain the old oil without somebody's getting extremely dirty. Secondly, such draining very rarely removes more than one-half the accumulated solids that lie in the oil-pan and immediately contaminate the new oil.

EUROPEAN CONDITIONS

THE industrial output of many countries is less than in the years before the war, because trade relations have been disturbed or because the daily hours of labor have been deliberately reduced; but the people are dissatisfied with any lowering of the standard of living and disposed to think somebody to blame for it. Nevertheless, outside of Germany and possibly Russia, production and trade have been larger in 1923 than in 1922 or any year since the depression began.

The main trouble is that during the war and since people have formed the habit of refusing to adjust themselves to conditions that they regard as hard or unusual, and of appealing to Governments for relief.

All of the evils of irredeemable paper currency, issued at the will of governmental authorities, have been seen again over nearly all Europe. All of the specious pleas in favor of easy credit for the purpose of overcoming unemployment, raising prices and helping debtors have been advanced and the proposals tried, until everybody has had enough of them. The theory that no concrete standard of value is required, that lawfully issued paper, bearing the stamp of the sovereign power and possessing the legal tender quality, does not need to be convertible into any other kind of money, that gold has no real utility and that its use as basic money has been due to the tyranny of mere custom or the interests of international bankers has been exploited in every corner of Europe, but nobody any longer repeats it. The chief reason for the paper issues has been the pressing need for means of meeting the enormous demands on the treasuries, swollen by unemployment doles and the increased cost of all State services.

Large reparations payments can be made only as all the German industries are fully employed and pouring a stream of products into the markets of the world. This evidently requires the cooperation of the German people, stimulated by the incentive of individual reward that is the mainspring of industrial activity everywhere. It requires also a complete reorganization of the monetary and fiscal system of Germany, and it is doubtful whether this can be accomplished without outside help, similar to that afforded to Austria. It is not likely that such help can be secured until a practical settlement of the reparations problem is reached.—National City Bank.

Control of Detonation

By G. A. Young[1] and J. H. Holloway[2] Annual Meeting Paper

INVESTIGATIONS indicate that detonation may be controlled by retarding the rate of combustion by chemicals added to the mixture, which serve to increase its specific heat and prevent excessive temperature, and by reducing the temperature of the walls of the combustion-chamber, so that the temperature of the charge previous to ignition will be lower and thus ensure a normal rate of combustion. The present discussion is devoted to methods of controlling the temperature of the charge before and after the mixture enters the combustion chamber, and before normal ignition occurs. Tests previously made on a poppet-valve engine and on a sleeve-valve engine revealed the impracticability of applying the laboratory methods used at that time to commercial practice and the need of eliminating some of the difficulties inherent in those methods of detonation control. The various changes made in the engine are described, including the specially designed spark-plugs. The conclusions drawn from the results of tests covering a period of 2 years are that, when reasonable care is exercised in maintaining the mixture, the spark-plugs, the valves and the combustion-chamber at the proper temperature, a compression-pressure of 125 lb. per sq. in. can be used without detonation by the addition of a small amount of anti-knock compound to the fuel with enough increase in the efficiency of the engine to warrant the additional expense.

THE control of detonation has long been a subject of interesting investigation and has been successfully secured in several ways. The results obtained at Purdue University indicate that it may be secured (*a*) by adding chemicals to the fuel, in which case the specific heat of the mixture is raised to a point that prevents excessive temperature, thus retarding the rate of combustion; (*b*) by reducing the temperature of the combustion-chamber walls so that a lower temperature of the charge can be maintained previously to the normal ignition, thus ensuring a normal rate of combustion.

Critical Temperature

Smooth engine-operation may be obtained at any condition below the detonation point, but after this point has been reached detonation persists over a wide range of conditions owing to the continuance of abnormal temperatures somewhere in the combustion-chamber.

Even though the general temperature of the mixture may be below the critical point just prior to ignition, the radiation of heat from some hot-spot in the combustion-chamber, such as a spark-plug, will raise that portion of the charge in contact with it above the critical temperature and detonation will occur. In fact, it is likely that the cause of detonation up to the critical temperature is usually or always a local condition in the cylinder.

Frequent sources of local high-temperature are found in the exhaust-valves and the spark-plugs. Everyone has observed that an engine that detonates badly when hot will often operate satisfactorily when cold. Also, by making the mixture excessively lean or rich, detonation below the critical temperature is often prevented.

Factors Affecting the Rate of Combustion

In the combustion of the present commercial lower grades of gasoline two distinct phenomena may be observed in gaseous mixtures. Combustion varies in speed from relatively slow to almost instantaneous, the controlling factors being the temperature and the state of aggregation, or density, depending on the pressure. The temperature apparently affects both the amplitude and the rate of the atomic or electronic vibration, and the pressure affects the density, both of which facilitate the dissemination of combustion throughout the charge. As the amplitude of the atomic vibrations increases, from the source of ignition to the extreme parts of the combustion-chamber, ignition is instantly propagated to all parts of the charge and results in detonation.

At some critical temperature, depending upon the character of the mixture, combustion is apparently instantaneous, resulting in a greater liberation of heat to the combustion-chamber walls and a consequent loss of power and efficiency. Whether this is due to dissociation, with a liberation of free carbon atoms or other particles, which become incandescent and act as radiators, is a subject the discussion of which is beyond the scope of this paper. By adding certain chemicals this instantaneous burning or detonation may be prevented or retarded to a great degree; but this discussion is devoted primarily to the second method of control, namely, the control of the temperature of the charge previously to ignition.

1922 Investigation of the Control of Detonation

The investigation of the control of detonation was begun in 1922 in the mechanical engineering division of the engineering experiment station at Purdue University. The work has been continued throughout the last year. Before the results of the 1923 investigation are discussed, a brief review of the results of 1922 will be given.

The purpose of the investigation was to determine how far the control of detonation could be effected by controlling the temperature of the mixture before and after the mixture entered the combustion-chamber and before normal ignition occurred. The results of the first part of this investigation were presented in a paper[3] entitled Internal-Combustion Engine Characteristics Under High Compression read before the Annual Meeting of the Society in January, 1923.

The Equipment Used in the 1922 Investigation

In the investigation previously reported two types of engine of standard design were used, namely, a six-cylinder poppet-valve engine and a four-cylinder sleeve-valve engine, the compression-ratio in both engines being 6.75 to 1, produced by redesigning the heads.

THE POPPET-VALVE ENGINE

(1) The engine used had a bore of 3¼ in. and a stroke of 4½ in.

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[3] See The Journal, January, 1923, p. 111.

(2) Standard porcelain-core spark-plugs were used, which were later changed to those with mica cores with heavy electrodes and water-jacketed shells
(3) The water-jacket was designed for thermosiphon circulation, but cooling-water was forced through the jacket by the pressure from the city mains, each cylinder having a separate inlet-pipe
(4) The carbureter was first bolted directly to the cylinder-block at the entrance to the water-cooled inlet-manifold. A hot-spot vaporizer was used to increase vaporization, but the high temperature of the mixture thus produced increased the detonation and was obviated by introducing an intercooler. Further benefit was derived from dropping the carbureter and the hot-spot 24 in. below the inlet-manifold and inserting a vertical water-jacketed pipe for cooling the mixture still farther to 125 deg. fahr.
(5) The original gray-iron pistons were superseded later by aluminum pistons of the same design
(6) The battery-ignition failed under the high compression and a high-tension magneto system was installed

THE SLEEVE-VALVE ENGINE

(1) The engine was a Model 88-4 Willys-Knight of 4⅛-in. bore and 4½-in. stroke
(2) Specially designed spark-plugs were used with shells in direct contact with the cooling-water
(3) The head was redesigned to give higher compression, and special attention was paid to securing proper water-cooling for all parts of the combustion-chamber
(4) A Model LB-2 Stromberg carbureter was used in connection with a hot-spot vaporizer and a long vertical water-cooled inlet-pipe. The mixture was reheated in the main inlet-manifold by jacket-water from the cylinder-block
(5) The cast-iron pistons were replaced by aluminum-alloy pistons
(6) A Model SS-4 Splitdorf magneto replaced the battery system

Summary of the Results of the 1922 Investigation

A summary of the results obtained on the two engines can be grouped under the heads of specific results and general results. The first includes the following:

(1) Automobile engines designed to give a uniform cooling of the combustion-chamber walls will allow much higher compression-ratios to be used than those employed at present, with a consequent gain in engine power and economy
(2) The compression-ratio of 6.75 to 1 gave a compression-pressure of 122 lb. per sq. in.
(3) The fuel-air ratio for maximum economy borders on the lean limits for reliable combustion
(4) For maximum power, the mixture-ratio need not exceed 0.075 lb. of gasoline per pound of dry air
(5) With concentrated heating of the mixture at the carbureter outlet, a local temperature of 125 deg. fahr. is sufficient to give good operation at full throttle. Cooling to 100 deg. fahr. at the valves is desirable if the compression-pressure of the engine is high. At part loads, a hot-spot temperature of 175 deg. fahr., with or without intermediate cooling, will give good results with lean mixtures

The salient features of the engine that allowed the carrying of high compression under all conditions of operation are

(1) Effectively cooled spark-plugs
(2) Comparatively cool exhaust-valves
(3) Uniform circulation in the water-jacket
(4) A carburetion system that gave good distribution with a low mixture-temperature
(5) Aluminum-alloy pistons
(6) An ignition-system capable of producing an adequate spark under high compression

1923 Investigation of the Control of Detonation

The brief review of the work accomplished during the year 1922, as summarized above, revealed, first, the impracticability of applying the laboratory methods used to commercial practice and, secondly, the need of eliminating some of the difficulties inherent in the 1922 methods of detonation control. These changes may be briefly stated in the following summary but will be discussed in detail, with the results accomplished by each in turn, later in this paper.

The Willys-Knight engine, Model 88-4, was replaced by a Willys-Knight sleeve-valve engine, Model 20, of 3⅝-in. bore and 4½-in. stroke. The engine was equipped with specially designed high-compression heads. The 24-in. water-jacketed vertical pipe used as an intercooler between the carbureter and the inlet-manifold was replaced by an air-cooled intercooler and the separately heated hot-spot by an exhaust-heated vaporizer. The remote belt-driven circulating-pump was changed to a conventional installation. The high-tension magneto system was changed to a conventional 6-volt battery system.

In the final construction of the spark-plugs in the 1922 investigation, it was thought necessary to have the spark-plug shells in intimate contact with the engine-cooling medium. From a commercial standpoint this is impracticable and the spark-plugs now used have been designed to overcome these objections. The manual control of the spark-advance that is suitable for laboratory investigations at constant loads is wholly inadequate for frequent acceleration as required in road operation. With this in mind, an automatic control actuated by the inlet-manifold vacuum has been developed.

The final changes now under way to control detonation have been the design of aluminum-alloy cylinder-heads with internal cooling-fins projecting into the water-jacket space.

Equipment Used in the 1923 Investigation

The plans for the 1923 investigation included not only the laboratory but the road-tests. All the modifications in this year's equipment, therefore, were made so as to be adaptable to road work. The detail changes in the apparatus and the equipment and the results obtained by such changes will be given at this time.

The Model-20 Willys-Knight engine used this year has a smaller bore and stroke than the sleeve-valve engine used in the 1922 investigation. The standard pistons furnished by the company were changed to Bu-Nite aluminum-alloy split-skirt pistons, having steel rings encased in the metal to secure a constant clearance. Four piston-rings ⅛ in. wide were used as a pressure seal. The head is well ribbed and, in combination with the aluminum, gave satisfactory results in carrying away the heat from the piston-head. This combination gives a good pressure seal, very little oil-pumping and excellent heat-transfer from the center of the head to the cylinder-walls.

Considerable thought was given to devising a method for furnishing a dry cool gaseous mixture to the cylinders. This was finally obtained by constructing a special inlet and exhaust-manifold. The mixture is hot-spotted immediately upon leaving the carbureter, thus ensuring thorough vaporization. The mixture is then carried

around the front of the engine to the opposite side of the cylinder-block. By making the walls of this intake-passage of aluminum equipped with fins, the air from the radiator fan cools the mixture before it enters the cylinders. The long intercooler produces four definite and desired results:

(1) A cooler mixture in the combustion-chamber, permitting compression without detonation
(2) A reduction of the pulsating effect on the carbureter, resulting in better performance
(3) A longer time for the particles of fuel and air to mingle, thus delivering a more homogeneous mixture to the combustion-chamber
(4) A more uniform pressure, which facilitates the filling of each cylinder with an equal charge because of the inertia effect of the mixture flowing in the elongated passage

The conventional cooling-system was changed from a siphon to a pump-circulating system. The cooling of that portion of the cylinder-head in direct contact with the hottest gases of combustion was accomplished by providing separate circulating pipes for each cylinder. These pipes extend downward from the water-outlet manifold to within ½ in. of the cylinder-head. This arrangement, together with a separate inlet-pipe for each cylinder, created sufficient velocity of the cooling-water to maintain the cylinder-head at a low temperature and prevent detonation at the point at which hot-spots are likely to occur.

The ignition was by the conventional 6-volt battery distributer system. To ensure results comparable with those of road operation, the battery was connected to the generator in the usual way.

The spark-plugs used in the investigation this year represent original designs developed to overcome the objections inherent in the spark-plugs used in last year's work. It is generally known that one of the chief requirements in designing a spark-plug for a particular job is that it shall operate at such a temperature that it will run clean, yet be cool enough not to detonate the charge. After designing and building several types of spark-plug, a satisfactory construction was finally secured. The first designs had porcelain cores and brass shells, with the smallest possible area exposed to the heat of the gases. Instead of using a copper-asbestos gasket, the porcelain was cemented into the shells in all the designs to secure a gastight joint. The cores were mechanically held in place by rolling the shells, and the electrodes were made as short as possible.

Some interesting characteristics were noticed when using spark-plugs built in the above manner. It was observed that when the spark-plugs were hot enough to cause preignition they would sometimes misfire for a period and continue to do so until they had apparently cooled somewhat. This observation resulted in an investigation of the effect of temperature on electrical resistivity, by an electric furnace, thermocouples and a constant-voltage megger. A number of porcelain as well as mica cores were tested to show the change in the resistance due to change in the temperature and it was found that the resistance bore a very definite relation to the temperature, decreasing as the temperature increased. The results were consistent but varied through a wide range with the various cores. The mica core showed a much higher resistance than the porcelain, particularly at high temperatures. The results showed further that some of the porcelain cores at high temperatures have a resistance sufficiently low to impair seriously the value of the spark. The use of these specially designed spark-plugs brought out a number of interesting facts, and as these all have to do with the control of detonation some of the most salient ones will be mentioned.

(1) The large area of contact between the shell and the core secured by the sealing cement provided an excellent path for heat-transfer, thus maintaining the core and the central electrode at the proper working temperature to prevent detonation
(2) The electrodes must be small in cross-sectional area so that not enough heat will be radiated to the charge to cause detonation, yet must extend deep enough into the mixture to ensure adequate ignition
(3) When the engine is started cold, the carbon that is always deposited on the porcelain, when it is maintained at too low a temperature, will short-circuit the spark-plug and result in misfiring. By counter-boring the shell adjacent to the porcelain the temperature of the porcelain was raised sufficiently to prevent the formation of carbon, yet was maintained cool enough to avoid detonation. This also increased the length of the electrical-leakage path and prevented misfiring because of the accumulation of moisture, as when starting cold

Summary of the Results of the 1923 Investigation

The results obtained from the modified equipment used in the 1923 investigation of detonation control have been summarized in the following paragraphs, and include only the laboratory investigations, as lack of time did not allow road-tests.

The effect of the timing of the spark on detonation control is as follows:

(1) The best spark-timing at full throttle, or at 125-lb. compression-pressure, is from 8 to 10 deg. in advance of the dead-center
(2) The change in spark-timing required between high and low compression varies more with the throttle opening than with the engine speed
(3) The engine was operated smoothly as low as 500 r.p.m. at one-fourth throttle with a spark-advance of 38 deg.
(4) With high compression the spark-advance is much more critical between the half and the full-throttle openings than at ordinary compression-pressures
(5) Carbon and other deposits in the combustion-chamber greatly affect the detonation problem insofar as they reduce the heat conductivity and increase the compression
(6) A high-compression engine with properly cooled spark-plugs and valves, when badly carbonized, will perform much the same as a normal-compression engine
(7) Cylinder deposits apparently are reduced by air-cleaning, improved lubrication and the use of properly proportioned dry mixtures
(8) A cooler mixture in the combustion-chamber permits higher compression without detonation
(9) A reduction in the pulsating effect on the carbureter results in better performance
(10) The longer passage gives an increased time for the mingling of the particles of fuel and air, thus delivering a more homogeneous mixture to the combustion-chamber
(11) The inertia effect of the mixture flowing in the elongated passage creates a more uniform pressure, which facilitates the filling of each cylinder with an equal charge

General Conclusions

The results of tests during the last 2 years lead to the following general conclusions:

(1) The conventional 6-volt battery-distributer ignition-system furnished reliable ignition when the battery was connected to the generator
(2) The aluminum-alloy pistons, with thick heads well ribbed, with four piston-rings, made it possible to carry a compression-pressure of 125 lb. per sq. in. without detonation, a thing that would be impossible with cast-iron pistons
(3) All the commercial spark-plugs used have been found to be the first cause of detonation
(4) When specially designed spark-plugs are used the way is open for the study of detonation produced by other causes
(5) It was found that spark-plugs can be designed and built which will operate at a sufficiently low temperature not to produce detonation and yet be practical
(6) Under the most favorable conditions as to the temperatures of the valves, the spark-plugs and the combustion-chamber walls, the heat of compression at 130 lb. per sq. in. compression-pressure is enough to detonate the charge after the spark has passed
(7) Engines of the poppet-valve type, using present-day low-grade fuel, with properly cooled combustion-chamber, spark-plug and valves, may be run at compression-pressures not to exceed 100 to 110 lb. per sq. in. without involving an undue amount of carbon cleaning
(8) A maximum compression-pressure of 125 lb. per sq. in., gage pressure, can be used without detonation when proper care has been exercised to prevent hot-spots, using properly designed spark-plugs and delivering a cool mixture to the combustion-chamber of a sleeve-valve engine

It may not be out of place to say in conclusion that it seems logical to believe that when reasonable care is exercised in maintaining the mixture, the spark-plugs, the valves and the combustion-chamber walls at the proper temperatures, a compression-pressure of from 125 lb. per sq. in. can be used without detonation by the addition of a small amount of anti-knock compound to the fuel with enough increase in the efficiency to warrant the additional expense.

SERVICE

(Concluded from p. 276)

the sale, and that your service is for the user's benefit. Then service will be easier to sell. Have your service-men sell the user on the quality of your cars, so that the man who leaves your front door as a prospect is not "killed" by what he is told at the garage door. It is far better to endeavor to have a service-man sell his company and its product in accordance with the company's idea, rather than his own. A few things a service-man has to sell are the following:

(1) The company and its product
(2) The reasonableness of the guarantee
(3) The necessity for the repair job according to the company's standard
(4) The use of his company's parts
(5) His price
(6) The need for having his automobile taken care of periodically
(7) The proper use and the avoidance of abuse
(8) The company's service
(9) Most important, the fact that the service station is being run for the benefit of, and in appreciation of, the users and not as a means of deriving another income from them

Teach the service-man how to sell these things intelligently. It pays in satisfied users, and satisfied users sell cars.

I cannot help but feel that we too often overlook the opportunity of meeting with those who are associated with us. Too often we get the idea that it does not pay. Perhaps we cannot measure the actual results, but some time in your visits around the Country compare the number of cars of different makes in the same price-class in various cities and you will get the answer as to whether service honestly and efficiently given and intelligently sold pays.

Someone has said, "Service is the big brother of sales." None of us will deny the truth of this statement; but, in all education of the users and of the service-men, let us not forget that *only good service can be satisfactorily sold.*

The Automotive Industry and National Defense

By BRIGADIER-GEN. C. L'H. RUGGLES[1], U. S. A.

ANNUAL MEETING ADDRESS *Illustrated with Drawings*

PREPAREDNESS and national defense, far from involving the idea of aggressive war on our part, merely serve to meet an obligation of the War Department, placed upon it by our forefathers, and are in accord with the universal experience that the only certain method of preventing an attack by an unprincipled aggressor is to be stronger than he. This Country possesses all the elements of strength that are necessary to deter an enemy from wanton attacks against it, provided it uses reasonable foresight in placing itself in condition to use its strength effectively if required. Manpower and munitions decide the issue, but manpower without proper munitions is hopelessly handicapped.

The automotive industry, the third largest in the Country in the value of its products, is an outstanding element of industrial strength; its vitality, progressiveness, flexibility and resources, the high character, patriotism and aggressiveness of its personnel, and its adaptability to producing munitions and automotive materiel make it an asset of the utmost value. The mobility of an army is vital to its success and the task of the automotive branch is that of supplying 20 or more fair-sized cities each of which is continually in motion.

During the recent war the manpower of the Country was ready to fight at least a year before the munitions had reached the quantity-production stage. Two things are therefore necessary: (*a*) to keep on hand a sufficient reserve of munitions to supply the troops until new production of munitions in quantity can be obtained and (*b*) to get into quantity production at the earliest possible moment and before the enemy can do so. As a result of the war the United States possesses an ample reserve of munitions but the ammunition component deteriorates rapidly and must soon be replaced.

The National Defense Act of 1920 delegates to the Assistant Secretary of War the duty of making adequate provision for the mobilization of materiel and industrial organizations that is essential to war-time needs. This includes a determination of the amounts of war materiel that must be kept on hand, when new production must commence, and at what rate it must continue. The succeeding steps involve the selecting of plants to manufacture the munitions, an agreement with their managements, the furnishing of necessary information as to the amounts required, the rates of delivery, the specifications, drawings and descriptions of approved methods of manufacture and the like.

To facilitate this work, the Country has been divided into 14 divisions, each under an ordnance district-chief, who is responsible for the work of his organization. An important step is the saving of the time that would otherwise be lost in negotiating the terms of war contracts after war has been declared. Contract forms are provided that are sufficiently flexible so that they can be executed in time of peace but will become effective only in time of war. These expire automatically at certain intervals unless renewed and may be canceled in time of peace after due notice by either party.

The underlying idea of the ideal system is that a telegram from the President authorizing the production of munitions of war shall start the immense production machine in motion immediately. It is the belief of the War Department that its plans will result in building up an industrial organization so strong that any foreign power will hesitate a long time before attacking the United States.

THE Ordnance Department of the Army during and since the war has had very close relations with the Society, officially through the periodic meetings of its officers with the Ordnance Advisory Committee appointed by the Society to consult with and advise it in connection with the development of automotive materiel for the Army and less formally through the many pleasant friendships formed between the members of the Society and the officers of the Department. The Department has benefited greatly by this close liaison and considers itself on this account very much indebted to the Society.

Apparently, in the minds of some of our citizens, the words "preparedness" and "national defense" involve the idea of an aggressive war on our part; these persons instinctively object, therefore, whenever the subject is mentioned. But this idea is fundamentally wrong. It is the business of the War Department, an obligation placed upon it by our forefathers, to advise the people as to what is necessary for their national defense. As a result of the experience of all the ages, the one certain method of preventing an attack by an unprincipled aggressor is to be stronger than he. No amount of unwillingness to fight or to defend oneself will stave off unprovoked aggression, but a knowledge on the part of the aggressor that, if he attacks, he will surely be defeated will as certainly deter him, as an unwillingness to defend oneself will encourage him to attack. Fortunately for this Country, it possesses all the elements of strength to deter an enemy from wanton attack against it, provided only it uses reasonable foresight in placing itself in condition to use its strength effectively if required.

In a modern war between major powers, the whole manpower of the Nation is engaged, either at the front in actual combat, or at home in the production of the supplies necessary for clothing and feeding the people and the munitions for supplying the fighting forces at the front. The two factors that will decide the issue are the quantity of the manpower and the quantity and quality of the munitions supplied to it. In the past when industry was in its infancy manpower alone decided the issue, but in these days the best of manpower, unless it is furnished with munitions approximately equal in quantity and quality to those of its adversary, is frightfully handicapped and, if the deficiency in munitions is sufficiently great, it is hopelessly handicapped. Imagine for example, what would be the outcome if the veteran legions of Caesar, armed only with the weapons of their

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time, should engage in battle with but one-tenth their number armed with the modern weapons used in the World War.

Our manpower, if properly supplied with munitions, is sufficient, both in quantity and in quality, to protect the Country from invasion by any power or combination of powers, and our industrial resources are the greatest in the world. But, unfortunately, industrial resources alone will not suffice any more than the brute strength of a novice will withstand the science and skill of a trained boxer. To render these industrial resources effective in the national defense, we must be prepared to produce munitions in time of national emergency in a quantity and of a quality at least equal to those of our adversary.

Position of the Automotive Industry.

One of the most outstanding elements of our industrial strength is the automotive industry, the third largest in the Country in the value of its products. Its accomplishments during the war were too numerous and too extensive to mention here in detail; suffice it to say that they were such as to excite the admiration and the gratitude of all our citizens that were in a position to know what was being done by it.

It is safe to say that at that time practically all the members of the Society, in one way or another, were actively engaged in the defense of their Country in uniform, as was your honored president, Colonel Alden, or as technical advisors to the various Government departments and agencies concerned in the prosecution of the war, or as engineers and managers of the plants of the industry engaged in the production of transportation, airplanes, tractors, gun-carriages, shells, bombs, grenades, fuses and so on.

In the vitality, the progressiveness, the flexibility and the enormous resources of the automotive industry, in the high character, patriotism and aggressiveness of its personnel and in its ready adaptability to the production of munitions of all kinds, the United States possesses an asset of the utmost value for the national defense. Beyond all this, the automotive industry has a very special relation to the national defense, so special, indeed, that, should a warring nation be deprived of its automotive materiel, it would at once be forced to capitulate. What could a fighting nation do if deprived of its airplanes, its motor trucks and passenger cars, its tractors and its tanks; all products of the automotive industry.

Vital as this materiel was during the war, its use undoubtedly will be vastly extended during the next great war. No one can foresee the ultimate development of aerial offense and defense, but we can rest assured that observation, pursuit and bombing airplanes, as well as airships, will play a far greater part in the next war than in the last, and that an adequate air-force adequately supplied with airplanes, airships and munitions will be vital to the national defense.

Army Is Dependent on Transportation.

There is also no doubt that the success of the army is dependent upon transportation. Beyond the railheads the army must rely on motor transportation for its very subsistence, as well as for the munitions with which it attacks the enemy. Modern warfare between great powers involves the employment on the firing front of millions of men, a single army-corps consisting of nearly 100,000 men, which is equal to the population of a fair-sized city. Imagine the task of supplying 20 or more cities by motor transportation alone; and add to this the transportation involved in bringing up ammunition

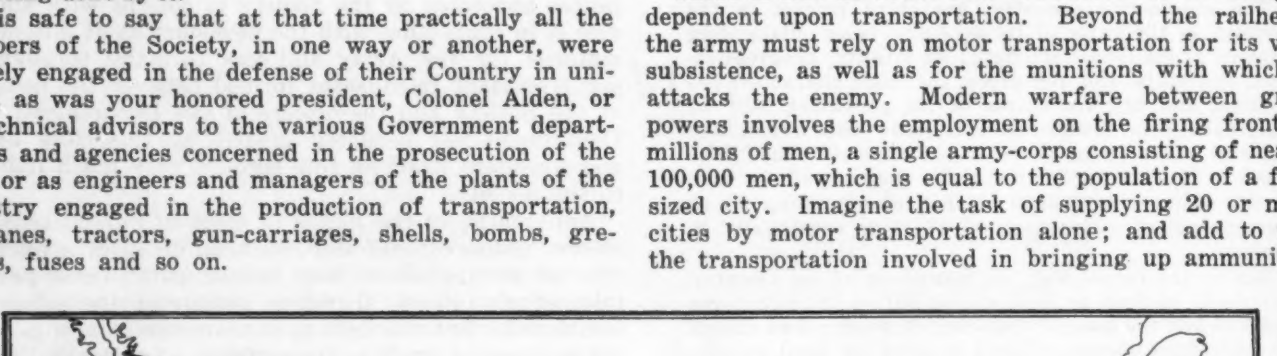

Fig. 1—Map Showing the 14 Ordnance Districts into Which the United States Has Been Divided
Each of the Districts Takes Its Name from the City That Has Been Designated as the Center of Operations. The Work in Each District for a Particular Procuring Service Is Supervised by a Prominent Business Man Who Resides in the District and Has Volunteered for the Purpose. Each Ordnance District-Chief Is Assisted by One or More Regular Army Officers Who Are Expected To Carry On the Routine Work of the District Under His Supervision

and evacuating the sick and the wounded. Then remember that this must be done for cities that do not "stay put" but are constantly moving about, and that they must be supplied over shell-torn roads, many of which will be under shell-fire at the time. I am talking only of troops on the firing-line, but it must be understood that even more men will be in the areas behind the line and that motor transportation is necessary for them also.

The mobility of an army is vital to its success. Heretofore, the maneuvers of an army have been limited by the number and the condition of the roads in the area in which it was operating. In the future, an army cannot afford to be thus hampered and hence arises the need of cross-country motor transportation that is certain to come in the near future. The use of tanks, another automotive product, is in its infancy, and no one can foresee the tank development of the future.

But the demands of the automotive industry will not be confined to materiel that in one sense may be called its own particular product. It must supply armament, bombs and fuses for the airplanes it produces; guns, gun-carriages, shells, fuses and other munitions for defense against airplanes and for more general use against the enemy, and all this to the fullest capacity of the industry in case we are involved in a war requiring our maximum effort.

We all know that it took us more than 18 months to get into quantity production of munitions during the war; and this experience was about the same as that of our allies. It was well established that we can give our young men a reasonable amount of training and send them to the front ready to fight at least a year before we can supply them with munitions from new production. But, of course, we must not send them to the front without munitions and, unless our enemy is surprisingly lacking in foresight, we cannot wait a year after our man-power is ready before we supply it with the means with which to put up an adequate defense of our country; and so you are entitled to ask, "What do we propose to do about it?"

Methods of Preparation

We can do only two things: First, keep on hand in time of peace a sufficient reserve of munitions to supply our troops until new production of munitions in quantity can be obtained; and, second, get into quantity production of new munitions at the earliest possible date after war has been declared, if possible, before our enemy does and, if we would avoid defeat, certainly as soon as he does.

Fortunately for us, the United States possesses, as a result of the war, a large reserve of munitions, sufficient, indeed, to supply our troops reasonably well until munitions can be obtained in quantity from new production. But, unfortunately, the loaded ammunition component of this reserve deteriorates with age and must be replaced from time to time. Small-arms ammunition deteriorates more rapidly than ammunition for cannon, and the time has nearly arrived when we must replace it, if our supply of rifles is to have any value. In a few years more it will be necessary to commence replacing our ammunition for cannon. The remainder of the reserve, consisting of cannon and other materiel that does not deteriorate in storage, will not be replaced until it becomes evident that one or more of the major powers are re-equipping themselves with similar materiel of more modern and effective types than those we have in reserve. Meanwhile, we ourselves are developing more effective types so that we may be ready to put them into production should the necessity arise. Our aim is to keep our war reserves as small as possible, consistent with national safety, so that the annual cost of upkeep shall not exceed a moderate figure and, in this connection, it is evident that the more quickly we can get into quantity production of new munitions, the smaller will be the war reserve that we must carry and the less will be the expenditure for its upkeep in time of peace.

In framing the National Defense Act of 1920, Congress had the benefit of the experience gained in the war and realized that in the present stage of industrial development an army without a supply of munitions equal in quantity and quality to that of its adversary is hopelessly and pitifully handicapped. It therefore included in this act a provision prescribing that

> The Assistant Secretary of War shall be charged with the assurance of adequate provision for the mobilization of material and industrial organizations essential to war-time needs.

Under the direction of The Assistant Secretary of War, therefore, the branches of the Army charged with the procurement and the supply of munitions are planning in time of peace for procuring munitions in time of war. In working up these plans, the guiding principle is to make them so complete that, so far as possible, nothing that can be provided for by planning in time of peace will be overlooked and cause confusion and delay after war has been declared.

War Department Plans for Meeting Contingencies

The War Department General Staff has prepared plans for the operation of the armies of the United States under the various contingencies that may develop in war. These plans show the number and the kinds of troops to be employed, how they shall be armed, how soon they shall be mobilized after the declaration of war and when they shall be sent to the fighting fronts. From these plans and from the experience gained in procuring munitions during the war, the procuring service of the War Department has developed what amounts of the various munitions must be kept on hand in time of peace, when new production must commence and at what rate it must continue. The determination of what is wanted and when it will be wanted is itself a great advance over the condition in which we found ourselves at the beginning of the war, yet it is but a preliminary step in the plans we are making for industrial preparedness.

Having determined what is needed and when, the succeeding steps involve the selecting of plants to manufacture the munitions, an agreement to that effect with their managements, and the furnishing to the managements of all necessary information, such as the amounts desired, the rates of delivery, the specifications, drawings and descriptions of approved methods of manufacture, and the like. This work is being done through a decentralized system as follows:

The United States has been divided into 14 procurement districts, for each of which a headquarters city has been designated. Fig. 1 shows these districts with their headquarters cities. The work in each district for a particular procuring service is supervised by a prominent business-man, resident in the district, who has volunteered for the purpose. In the Detroit district, for example, the ordnance district-chief is Col. H. A. O'Dell.

For the present, each ordnance district-chief is furnished with one and, in some cases, two regular ordnance-officers as executive assistants, who are expected to carry on the routine work of the district under the supervision

of the chief. As our plans progress, it is not unlikely that it will be necessary to increase the force of regular officers in each district.

In time of war these district organizations must be vastly increased, as the district chief, under the general supervision of the Chief of Ordnance, will be charged with the procurement, production, inspection and acceptance of all ordnance produced in his district. The same will be true of the district chiefs for other procuring services. The district chief will also be charged with the settling of all contracts in his district that will be terminated by the close of the war.

Duties of the District Chief.

One of the duties of the district chief during peace is to plan the district organization for war and to select and assign in advance the personnel required for that organization. For this purpose, ordnance officers of the reserve corps are assigned to the various districts but only with the consent of the district chief, for he is responsible for the work of his organization and should be furnished only with assistants satisfactory to him. The district chief is encouraged to select persons to be commissioned as reserve officers for assignment to his district during war and, if he chooses, he may arrange with persons to take over important duties in a civilian capacity during war, if for any reason he prefers that arrangement. The majority of the ordnance district-chiefs have accepted commissions in the reserve corps, while others prefer to retain a civilian status. This matter is optional in each case.

The work of the various districts has progressed very satisfactorily considering the relatively short time the districts have been in operation; and in December, 1923, each district-chief submitted his war plan, which embraced his proposed war organization, the assignment of individuals to the most important key positions, a statement of the war orders received, the tentative allocations of orders to plants and other important matters relating to the work in hand and in prospect. These war plans will be revised and submitted yearly as the work progresses.

A most important step in industrial preparedness is the saving of the time that otherwise would be lost in negotiating the terms of the war contracts after war had been declared. A War Department board, therefore, is engaged in the preparation of contract forms for use in war, that are sufficiently flexible in their conditions to permit of their being executed in time of peace, but will become effective only in case of war. It is the intention to have these contracts, when signed in time of peace, automatically expire unless renewed after certain prescribed intervals, as from 3 to 5 years. They can also be canceled in time of peace after due notice by either party. It is the aim of the War Department to prepare a form of contract that will be eminently fair to both parties, that will provide for reimbursing the contractor as fast as he expends funds in the prosecution of the contract, that will avoid, so far as is humanly possible, any lack of definiteness of terms and conditions, and that will provide for the promptest possible settlement upon their completion, or upon termination by reason of the ending of the war. In preparing these contract forms the War Department is seeking the help and advice of many of the leading contractors of the war.

But even if requirements for munitions have been determined and allocated to the various districts, have been split up and allocated by the chiefs thereof to the various manufacturing plants in the districts, and contracts have been executed with the managements of these plants, much yet remains to be done in order to clear the way for the quickest possible production after war has been declared. It is evident that to secure the amount of industrial preparedness that the War Department desires, there must be whole-hearted and patriotic cooperation by industry and, therefore, each plant selected for the production of munitions will be urged to work out its own plans for the production assigned to it, in as great detail as may be practicable in each case.

The Ideal Solution

The ideal solution would be one in which the plans shall be so complete that the requirements of each district as a whole, for fuel, power, transportation, raw materials, labor and storage shall have been carefully worked out, and that each firm selected for munitions production shall know from whom it will receive its raw or partly finished materials, its machine tools, gages and other facilities not on hand or intended to be purchased by it, where it shall get its labor and where it shall ship the work completed by it. In such an ideal case, all that would be required to start the immense production machine in motion would be a telegram from the City of Washington that the President has authorized the procurement of munitions for war.

Finally, it is the hope and belief of the War Department that the industrial war-plans that it is making with the cooperation of industry will, in the aggregate effort and without requiring too much of the individual manufacturer, build up an industrial organization for war so strong that any power or combination of powers will hesitate long before seriously preparing to attack the United States.

Any practicable plan that will prevent, or at least materially shorten, a modern war with its attendant losses of capital and of young lives is worthy of the most serious consideration of every patriotic American citizen, and it is, therefore, with the utmost confidence that I ask so progressive and patriotic a body as the Society to lend its aid in this great movement for continued peace.

Relation of Intra-Company to General Standardization[1]

By E. A. JOHNSTON[2] AND O. B. ZIMMERMAN[3]

THE efforts being made in all lines of industry to accomplish what is included in the general term "standardization" are receiving and have received considerable attention by individual agricultural implement manufacturers, yet what has been done is far from what can, and will be, accomplished. A constructive program is now being followed in an attempt to apply standardization by each of several larger groups of plants or firms of this industry, but little has been done toward national or international standardization.

As this general effort is very extensive, and as it involves a distinctly economic problem, it must be viewed in all its phases from that standpoint. The term "economic" is used here with the idea that it fully includes everything affecting costs and sales price, as well as design features which will of necessity be given more emphasis in this paper.

Unless each separate item receiving consideration in this program, as well as the whole program, is worked out in this manner, it is bound to go through serious economic changes and long delays before arrival at what should be the standard. This means ultimately a needless and heavy loss to this industry and to those who use its equipment.

All solutions must be mechanically and commercially sound from the standpoints of the manufacturer, the distributor and the consumer. All interested parties must have their economic interests considered and properly weighed with respect to all the others interested; otherwise the result will be unsatisfactory and temporary.

NATURE OF STANDARDS

Standardization should be, then, a logical method of arriving at a mechanically and commercially sound economic solution of the problem, in the most sensible manner and at the right time.

Any standard arrived at must still be considered as tentative and subject to periodic revision and improvement if and when requirements warrant such changes. This is especially true during the development period of a new device or machine.

The history of disconnected efforts at standardization shows that many of these efforts are the results of drifting under economic pressure rather than of a well-planned and logical program of effort. In company standardization this drifting under pressure often results in serious errors of conclusion because of snap judgments, individual notions, eccentricities or inadequate data.

Today we can say that even in the agricultural-implement industry, as well as in our own language, we are far from having a complete understanding as to terms and their use. Terms developed in a new industry readily find their way into international language, as for example the terms used in telephony and radio, but unless some effort is made in our own industry, which is long established and which undoubtedly leads the world, little can be gained in an international way toward the correct use of our terms.

Standards of straight screw-threads and pipe threads are now being worked out by the concerted efforts of many interests and arrival at an economic solution is practically in sight. What earlier was simply a standard relation between the diameter and the number of threads is much more complete today as it covers various standards of fit, their manufacturing tolerances and their methods of gaging, resulting in a higher type of standard. Uniform methods of making gages and of gaging screw products have not yet been adopted and until this phase of the problem is cleared up the solution cannot be called complete. Nevertheless, the extensive work on screw threads is a real triumph in engineering.

The S. A. E. fine-thread series, as distinguished from the older United States, or coarse-thread series, showed what can be done to meet the definition given earlier for standardization.

It has taken long years of drifting to settle down on the question of the various gages of sheet metal. Up to 1893, sheet iron and steel thicknesses were arbitrary, but today they are standard, although the whole question of gaging of other materials in practice is still very much unsettled.

World-war necessity gave a great impetus to work on the standardization problem, attracting wide interest and providing the necessary pressure to bring results. Much of the work was done under what should be classified as "elimination" and "simplification," as well as true "standardization."

In our agricultural-implement industry standardization program we must analyze the grand problem in an economic manner, using the utmost foresight and not go plunging on to disconnected hit-and-miss standards that later might be hard to eliminate. Every standard must be arrived at only after deliberate, careful thought and investigation.

AGRICULTURAL-INDUSTRY STANDARDIZATION

With these points in mind, we may review those efforts that have been made in the past and organize at least a constructive outline and grouping of possible economic standardization problems that can receive conscientious attention as time and importance permit.

The International Harvester Co. has, in the past, given much attention to this problem and something can be gained from a review of its work along this line. This company was formed by the uniting of several companies manufacturing similar lines; each with its individual designs, involving various satisfactory solutions of similar problems; each emphasizing special points for sales arguments, and avoiding the patented features of the others.

It was obvious upon the formation of the Company that, while the respective lines were to be preserved, elimination of needless varieties within these lines would be required and that selections should be made for continuance in manufacture of those features of engineering design that had been shown by experience to be mechanically and economically sound. This concentration certainly resulted in benefit to all who were affected, the designer, the manufacturer, the suppliers of raw material, the distributor and the user. It simplified and facilitated mass production, reduced inventories and facilitated the interchange of material between works. It also established more uniformly graded sizes of machines, thus reducing the costs of production and permitted this reflex to assist relative price reductions. As the work continues, these benefits are more and more emphasized.

With the development of new lines of manufacture by the Harvester Company, the engineering problems are much more difficult than those of an organization making fewer kinds of machines. The so-called distinct lines manufactured now number 60 and are listed in Table 1 according to group names that indicate the dominant functions of the machinery. The total number of lines in the farm implement industry as a whole is much greater than this. Any one of these lines, with the various sizes and their attachments, would consti-

[1] Paper, substantially in full, presented at the annual meeting of the American Society of Agricultural Engineers, Nov. 8 to 10, 1923.
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tute a considerable manufacturing proposition in itself. The coordination necessary is complicated but permits the gradual standardization that is going on by virtue of improvements, adoption of new materials, establishment of new designs or sizes, and improvement in manufacturing equipment.

TABLE 1—INTERNATIONAL HARVESTER CO. PRODUCTS ARRANGED ACCORDING TO GENERAL GROUPS

General Groups	No. of Lines
Deep-Tillage Implements	5
Surface-Tillage Implements	6
Planting Machinery	4
Cultivating Machinery	4
Haying Machinery	5
Machines for Preparing Crops for Market Use	9
Harvesting Machinery	9
Fertilizing Machinery	4
Dairy Machinery	1
Power Machinery	1
Automotive Machinery	2
Transporting Equipment	2
Miscellaneous	8
	60

We may define standardization that covers work of this character within a given company, having plants at various points, intra-company standardization, as distinguished from general standardization among several companies in a given industry.

The phases of standardization of these 60 lines of agricultural equipment can be grouped as follows:

(1) Nomenclature
(2) Materials, their specification and selective use
(3) Processes peculiar to these materials
(4) Design, practice, procedure and data
(5) Machine elements, parts and fittings
(6) Machine units
(7) Complete machines
(8) Attachments and equipment
(9) Methods of test, test reports and research

NOMENCLATURE

Nomenclature covers the complete naming and defining of the terms used in this industry. On this particular subject this Society can do much toward standardization. Further, it is fully as important that any Society conclusions should be passed on to the dictionary producers to make its efforts generally useful at the earliest date.

MATERIALS

Materials, their specification, and selective use, covers without going into too refined details, (*a*) iron and steel products, (*b*) non-ferrous metals, (*c*) textiles, fabrics, leathers, rubber goods and fiber, (*d*) wood products, (*e*) lubricants, fuel and chemicals and (*f*) miscellaneous..

In the case of each and every material that goes into manufacture, whether the raw product be created within the Company organization or purchased from without, it is desirable to have sensible commercial specifications to cover its composition, physical properties, dimensional standards, dimensional tolerances, cutting lengths and variations, finishes, weight tolerances, supply instructions, inspection data and tests.

As far as practicable, general specifications covering groups of stock are drawn to cover: General steels, hot-rolled and cold-finished; sheet steel and wire products. Alloy-steels are included in the first group. Where special requirements are demanded of material as to composition or dimensions, individual specifications are written up.

To show the thoroughness with which this class of work is being done, it may be said that no angle of information is overlooked in developing sensible commercial specifications. The committee handling this work has representatives of thorough experience in the engineering, manufacturing, purchasing and inspection departments and the chemical and physical laboratories, and wherever necessary other departments, such as sales, traffic, patent and auditing, are represented. Each specification is further reviewed and concurred in by the representatives of the raw-material producers.

The semi-final draft is thoroughly circulated within the company for criticisms by all others interested, whose knowledge of this industry's requirements would be helpful in avoiding even minor undesirable features. The criticisms made are incorporated in the final decision to which all conform. The advantages of this thorough review, which is similar to engineering society committee work, may be briefly indicated as follows:

A graded series of Bessemer, open-hearth and alloy-steels, many of which were made to conform to S. A. E. standards, was selected to cover the minimum number of varieties with the maximum number of uses, without sacrificing quality or product. The total number of steels was reduced from 73 to 38 in the past 2 years as shown in Table 2.

TABLE 2—REDUCTION IN KINDS OF STEEL

Grade of Steel	Number of Kinds Former	Number of Kinds Present	Reduction, Per Cent
Bessemer	42	12	28.6
Open-Hearth	24	18	75.0
Alloy	7	8	11.4[a]

[a] Increase.

To produce creditable products, the processes going with the above-noted groups of materials involve much that is related to manufacture. Large expenditures made in equipment and plant arrangements to carry out a project often interfere with the immediate adoption of a newly developed process that is economically desirable; hence in the International Harvester Co. long researches are frequently necessary before new standard processes can be adopted and put into use.

Under the head of processes in manufacture may be noted the following

(1) Chilled-iron practice
(2) Die-casting
(3) Enameling
(4) Heat-treating
(5) Iron mixtures
(6) Malleableizing
(7) Packing
(8) Painting
(9) Rust prevention treatment
(10) Varnishing

DESIGN

In adopting specific design characteristics to run through a series of sizes to incorporate the sensible maximum of desirable mechanical features, with regard to cost production and sales requirements, there is bound to be wide difference of opinion as to policy. Shall the object aimed at be a low-cost product, manufactured at a minimum price? Or shall it be a very high type of construction that must be sold at a high price? Or what shall be the sensible compromise of good quality and fair price?

Each product must stand a review by the management from this viewpoint and be accepted or rejected according to the economic status that it desires the product to occupy.

Design standards may be grouped as follows:

Machine Size Dimension Standards

Drill widths
Engine sizes
Ensilage cut width
Mower cuts
Plow-cut widths
Thresher sizes, by cylinder, number of teeth and speed
Tractor sizes
Truck sizes and wheelbase designations

Construction Dimensions

Allowable bearing-pressure
Bolt and nut size
Bushing proportions

Gear and tooth pressures
Press fits
Pulley diameters, widths and crown
Running fits
Rules regarding tolerances for fits and sizes of special mating parts
Screw-thread tolerances and fits
Taper fittings
Structural standards and preferred sizes of shafts, bolts and nuts, pipe, rivets, steel bars; structural sections

Practice

Factors of safety
Dust-proofing
Lubrication
Methods of gaging
Method of rating
Methods of test for ratings and capacities
Oil-grooving
Spring design formula and method
Strength of materials and preferred formulas
Working stresses under various conditions
Weight distribution on wheels

Each and every one of these items is under review by the Company engineering board, the engineers and the superintendents of experiments and each has evolved or is gradually evolving into a standard.

This list clearly indicates considerable possibility of general standardization. Some general standards can be borrowed from other industries with or without modification to meet this industry's needs. These should be adopted in the interest of general standardization.

Machine Elements

Certain simple elements exist in every machine produced, which repeat themselves in function in other machines and may have either shape or size that will be peculiar to an industry. We have, for example, gears, axles, keys, chain and belts. By a systematic study of the requirements of each of these elements and the establishment of a minimum number of graded sizes, making them uniform throughout the company's production, we may establish much in the way of standardization.

It may be that only certain general applications will tend toward general standards, but in the majority of cases thorough analysis will permit the establishment of basic design features, relations and proportions that can be adopted as company standards.

It is in this group that much can be done toward general standardization in the farm-implement industry.

A brief list of such elements follows:

Bearings—plain, bushed, roller, ball, thrust, removable
Bolts—machine, carriage, plow, special
Chains—malleable, steel, link, roller, silent
Gears—spur, bevel, spiral, worm, skew
Hubs—malleable, steel, cast, tube
Keys—square, gib, feather, taper, Woodruff
Levers—hand, foot, lifting
Nuts—plain, lock, special
Pulleys—plain, crowned, flanged, grooved, lagged
Screw-threads—coarse, fine, square, special
Spokes—round, oval, flat
Springs—tension, compression, torsion, special
Washers—lock, plain
Wrenches—socket, open, monkey

Machine Units

Some groups of machine elements work together as complete units to accomplish some specific purpose. These units appear in a number of machines and hence lend themselves to standardization. For example, a carbureter, a magneto, a clutch or a wheel.

If these units are reviewed and graded into steps to meet the minimum to the maximum requirements of the company, a noticeable saving can be made in their manufacture. Each example has to be reviewed separately to see whether both company and general standardization is practicable. Examples of such machine units are:

Air-cleaners
Belt tighteners
Carbureters
Couplings
Clutches—disk, taper, cone and slip
Engine units
Governors
Mufflers
Power take-offs
Spark-plugs
Wheels—carrying, drive, truck and tractor

Complete Machines and Equipment

Any manufacturer can establish a series of sizes of machines that seem to him desirable to meet the trade, but his judgment in this respect may be different from that of another manufacturer. Just how far coordination in establishing a general series can be accomplished remains to be seen. In many lines custom has developed unity.

Obviously, from the user's standpoint, such standards are desirable. For example, a farmer buys a tractor from *A* and his thresher from *B*. While by using a compromise in pulley size the required speed-adjustment can be made, still better cooperation will result if both *A* and *B* adopt standard belt-speeds.

Attachments and Special Equipment

Much confusion would be avoided if our industry were to establish understandings regarding what is regular equipment and what shall be classed as special attachments, equipment and devices. For example, shall a tractor be listed to the public as a stripped machine or shall it carry as regular equipment what would otherwise be called special attachments? Shall the governor, wheel-guards and the belt pulley be regular or special equipment on a tractor? What shall the tool equipment be? How far shall the user be required to go with regard to attachments before he is properly equipped and protected?

Research

Under the heading of methods of tests, standards, reports and research the agricultural engineers can do much to further general standardization. These results will be accomplished by the extension of such work as is under way at the University of Nebraska on tractor tests, at the University of Wisconsin on ensilage cutters, at the University of California on air-cleaners, at Alabama Polytechnic Institute on tractor lugs, and so of numerous other investigations that relate to farm equipment.

Basic data will be thereby established or indicated, aiding in making our industrial progress less of a groping in the dark toward future requirements of the industry. Important problems in regard to soil preparation, pulverization, cultivation, spraying, fertilizing and the distributing of seed are being worked out. Problems covering drainage, irrigation, farm sanitation, water supply and distribution, farm structures and equipment, all have possibilities for the development of general standards. The results of this extensive research work will enable companies engaged in this industry to use their imagination and abilities to a greater degree than ever before, and put us more completely in the same class with those industries that are using Science to the limit.

To enumerate even a small part of what has been accomplished in the Harvester Company along the lines indicated above would be impossible in the time available for this paper. Any such general comparison would depend on the period covered, the state of development of the particular machine considered, and questions of discontinued or added lines.

To illustrate what has been done in the case of only one of the many machine elements, coiled wire springs of the round wire, tension and compression types, we may mention the following standardization:

Establishment of definitions of terms peculiar to that product
Specification of material
Reduction of wire gages used from 6 to 1
Reduction of wire sizes from 51 to 31
Concentration of spring manufacture in one works
Establishment and unification of the heat-treatments
Reduction in design methods from 7 to 1
Development of design tables covering strength, load, and coil diameters, with safe ratios to use for avoiding material waste
Establishment of standard spring-ends, thus reducing breakage
Establishment of fatigue values to accord with spring operation
Establishment of standard drawing of springs at all works
The reduction in the number of springs from over 800 is under way, and the establishment of a series of preferred springs has begun

The above is an example of what can be done by intra-company standardization of one of the hundreds of possible machine-elements. It represents notable savings when considered in terms of more than 3000 tons of springs used yearly.

As an instance of unit standardization in Harvester Company products we cite the power unit. The three-point support, ball-bearing engine is developed in three sizes and used as follows:

The 3¾ x 5-in. four-cylinder on harvester thresher and two sizes of truck
The 4¼ x 5-in. four-cylinder on heavy trucks and the 10-20 tractor
The 4½ x 6-in. four-cylinder on the 15-30 tractor

TABLE 3—PROGRESS MADE IN THE ELIMINATION AND STANDARDIZATION OF COMPLETE MACHINES FROM 1915 TO 1923

Kind of Machine	Types in Use 1915	1923	Decrease, Per Cent
Corn-Shredders	12	4	66.7
Corn-Separators	18	5	72.2
Disk Harrows	286	68	76.2
Engines	130	4	96.9
Feed-Grinders	18	9	50.0
Peg-Tooth Harrows	46	11	76.1
Plows	398	271	31.9
Stalk Cutters	9	3	66.7
Spreaders	42	2	95.1
Tractors	15	3	80.0
Wagons and Gears	2,102	164	92.2

These engines are readily adaptable to further extensive use.

To illustrate what has been done in the way of elimination and standardization of complete machines, covering types and sizes, Table 3 has been prepared.

The net reduction in types and sizes covering all lines averages nearly 70 per cent for the same period.

Conclusion

This outline of standardization is comprehensive and workable. Such a program, it is believed, will serve adequately as a basis upon which to build a larger program covering all products and their parts included in the agricultural engineering field.

The standards to be developed must be fully consonant with the spirit of standardization and not hamper but rather encourage competition in ingenuity and development. Standards must have the effect of economically raising the qualities and the serviceability of the machines without seriously increasing their cost and place in the users' hands materials, designs, elements, units and complete machines that will be examples of first-class engineering, when viewed from the several economic standpoints surrounding the respective product.

Each standard must be developed to a high degree by itself. It will then naturally take its place as a company standard or a general standard.

Having reviewed this industry's products in some detail, we cannot refrain from calling attention to the fact that powerful and increasingly important economic influences are acting upon the industry. The effect of these influences is to cause future development to tend in certain well-defined directions.

We refer to such forces as the availability and the use of better materials, the application of the material to design characteristics, their influence on production, the factors of transportation and distribution costs covering products of both factory and farms, the effect of increased farm-labor costs, the demand for speed of accomplishment and the call for greater productivity per man per farm-unit area, the demands for better service between the manufacturer and the consumer and the necessity of greater conservation of crops until they reach the ultimate consumer.

These influences make it imperative for us to modify and to improve present designs accordingly. They should cause us to bring out new products fully commensurate with them. The standardization program we have outlined is essential in this connection.

Does it not behoove all of us, then, to lend our influence and support to a sensible alignment with this important economic movement?

LABOR AND LEADERSHIP

PERHAPS the most important present questions are those concerning labor. No fact has been more invariably confirmed in my long experience and my reading than that the progress of mankind has come by a few men being evolved in advance of the rest and leading them on. No law of nature to whom we conform our daily conduct, not gravitation itself, is more clearly established than that. Who put down the rebellion? Grant. Who whipped Germany? Foch. No human being ever answered "Grant's army" or "Foch's army," not even the men in the armies, themselves. Long before any grouped industries existed one of the authors from whom the Greek reader of my youth was compiled, wrote that an army of stags led by a lion would whip an army of lions led by a stag. But people recognize this regarding armies much better than they recognize it regarding industries. Yet at all times enterprises go into bankruptcy under one manager, which are picked up, with the same plants and the same workmen, by another manager and carried on successfully.

Among those who see pretty much everything made by the hands of workingmen, comparatively few realize that unless some one of wider intelligence tells those workingmen what to make, their product is very apt to be unsalable; that unless they are told how to make it, it is apt to be wastefully and ineffectively made; that unless some one provides them with the materials, tools, working-place and maintenance until the product is sold, it is not apt to be made at all; and that unless someone markets it skillfully, it will, practically without any exception, be sold at a disadvantage and inadequately paid for.

Unless industry is conducted by its natural leaders, and the parties get their natural shares, there is no product to divide. The biggest example is Russia, but small ones can be found in every American village.—Henry Holt.

Automobile Upholstery Leather

By K. L. HERRMANN[1] IN COLLABORATION WITH FRANK J. RADEL[2]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

FIRST referring to a bulletin that lists the natural defects of hides and gives hide classifications, the authors explain many of the technical terms used in leather manufacture and present an illustrated detailed description of the process by which a hide is transformed into upholstery leather suited for automobile use. The defects are technically known as grubs, brands, wire scratches, knife-cuts, scores and hair-slips, and their influence on the finished product is stated; then a hide is followed through the different stages of its transformance into leather from its green salted state.

After opening the bundles of hides and trimming from them the heads and the long shanks left on by the packer, the tanner puts each hide through the several processes of beaming, liming, unhairing, fleshing, deliming, tanning, splitting, re-tanning, sumac treatment, wet-tacking, shaving, softening, patching, japanning, doping, swelling, embossing and graining. Detailed control of all these is essential and is accomplished mainly by special machines and through utilizing the practical knowledge acquired by the operatives.

Difficulties attendant upon preparing a satisfactory leather specification are stated and a method of patching hides is mentioned that, it is expected, will be productive of large savings for the tanner and for the automobile builder. Hide shapes and cutting losses are discussed also and improvements in practice are recommended.

IN attempting to prepare a specification for automobile upholstery leather, the tanners called attention to natural defects that are beyond their control. These defects, as well as hide classifications, are described briefly in Farmers' Bulletin No. 1055 issued by the Department of Agriculture and dated August, 1919. In this bulletin hides are classified as "country" hides and "packer" hides. Packer hides are best because of uniform take-off, fewer cuts or scores, uniform trim and proper size and weight classification, due to the more experienced operatives available in packing-houses as compared with the work done by the country butcher. A second classification, which is worth considering for automobile leather, separates hides for size and weight: "Native spready steers" are hides weighing 60 lb. or more and measuring 6 ft. 6 in. just behind the brisket; "heavy native steers" are those measuring less than 6 ft. 6 in. behind the brisket and yet weighing 60 lb.; butt-branded steers or Texas steers are classed with South American hides and correspond to native spready steers except that they have one or more brand-marks. The heavy native cowhides are of interest, because it is claimed that the number of spready-steer hides available is limited, and that cowhides must be used to maintain the supply of upholstery leather.

Hides are classified further into "koshers" and "gentiles," because of the difference in the trim at the head. Kosher hides must have the head cut off entirely, while gentile hides have that portion covering the head at-

FIG. 1—THREE TYPES OF HIDES AVAILABLE FOR AUTOMOBILE UPHOLSTERY LEATHER

From Left to Right These Are a Stuck Throat or Gentile Spready Steer, a Cowhide and a Cut Throat or Kosher Spready Steer. The Terms Stuck Throat and Cut Throat Are Self-Explanatory. The Difference between a Gentile and a Kosher Hide Is Found in the Trim at the Head, the Former Having the Portion Covering the Head Attached, While the Latter Has the Head Entirely Cut-Off. A Spready Steer Is a Hide Weighing Not Less Than 60 Lb. and Measuring 6½ Ft. Immediately behind the Brisket. As It Is Claimed That the Supply of Spready Steer Hides Is Limited, Cowhides Are Used To Maintain the Supply of Upholstery Leather

tached. Because of this, kosher hides must measure 6 ft. 8 in. behind the brisket instead of 6 ft. 6 in. as for gentile hides. Also, kosher hides sell for about ½ cent per lb. less than gentile hides. Typical hides of three classes are shown in Fig. 1. The defects in hides are: (*a*) "grubs," (*b*) "brands," (*c*) "wire scratches," (*d*) "knife-cuts," (*e*) "scores" and (*f*) "hair-slips."

Grubs are open holes about ⅛ in. in diameter that are made through the hide by a grub, after it has matured under the skin of the animal, to get out. For No. 1 spready-steer hides, five grub-holes are allowed. Those having more than five grub-holes constitute No. 2, or glue stock, depending upon the extent of the damage. The terms "brands" and "wire-scratches" are self-explanatory. Knife-cuts are due to cuts made through the hide in taking it off, while scores are knife-slips that do not go through the hide. Hair-slips are caused by decay of the hide before being salted, or by uneven salting.

The hides are purchased from the packer by the pound, in a wet green salted-condition, and bundled as shown in Fig. 2. Hides of the summer and the fall kills of cattle are the more desirable, as they are shorter-haired and cleaner than those produced in winter and in early spring and generally are free from grub-holes. The tanner's first operation is to open the bundles and trim from the hide the heads and the long shanks left on by the packer; this eliminates considerable waste for the purchaser of the finished product. These trimmings, amounting to about 6 to 8 lb. on stuck-throat hides obtained after gentile slaughter and 10 to 12 lb. on cut-throat hides obtained after kosher slaughter, are sold at a great loss by the tanner; they are used in the manufacture of glue, soap, greases and fertilizer.

BEAMING

The next operation is that of soaking the hides. This is essentially a process of softening and cleaning, by

[1] M.S.A.E.—Assistant manager, Studebaker Corporation of America, Detroit.

[2] President, Radel Leather Mfg. Co., Newark, N. J.

FIG. 2—THE FIRST OPERATION IN CONVERTING A HIDE INTO LEATHER
The Hides Are Purchased in a Wet Green Salted Condition from the Packer and Arrive at the Tannery in Bundles. Opening the Bundles and Trimming the Heads and the Long Shanks Left on by the Packer Is the Tanner's First Operation. These Trimmings Amount to from 6 to 8 Lb. on a Gentile Hide and from 10 to 12 Lb. on a Kosher Hide and Are Sold for Utilization in the Manufacture of Glue, Soap, Greases and Fertilizer

submerging the hides in vats of clear water; it removes dirt, blood, dung, and salt and other preservatives, and restores a hide to the condition in which it was before curing.

After having been partly soaked, the hides are lifted from the vats and brushed by a machine, such as is shown in Fig. 3. The brushing operation consists of removing the fat from the flesh side of the hides by a rapidly revolving steel-bladed cylinder that is adjusted properly; a rubber roll carries the hide to this cylinder and the grip-rolls pull it out. The stringy pieces of fat that hang from the edges of the hides are trimmed off; the hides are then submerged again in vats of water for additional soaking and cleansing, in preparation for liming.

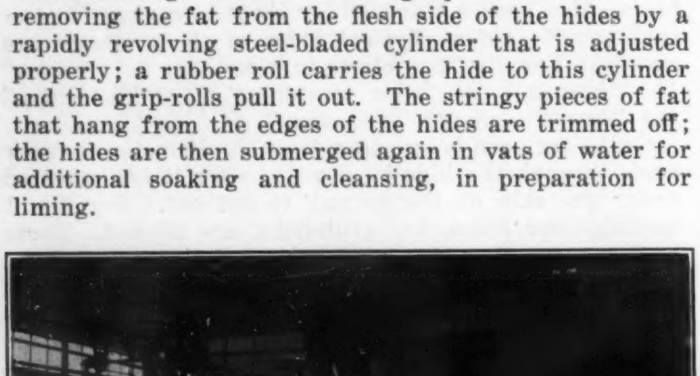

FIG. 3—THE START OF THE BEAMHOUSE
After Being Trimmed the Hides Are Soaked in Clear Water, They Are Brushed by Machinery when in a Partially Soaked Condition To Remove the Fat from the Flesh Side. This Is Done by the Steel-Bladed Cylinder as Shown in the Background at the Left. The Stringy Pieces of Fat Hanging from the Edges of the Hide Are Trimmed Off and the Hides Are Again Placed in Vats of Water for Further Soaking and Cleaning. In the Foreground at the Left Two Men Are Trimming a Hide and the Soaking Vats with Some Hides Being Prepared for the Liming Operation Can Be Seen at the Right

LIMING AND UNHAIRING

In the liming or unhairing process the hides are immersed in milk of lime made by slaking quicklime and adding water until the solution is of the strength desired. Several lines of vats are shown in Fig. 4. The hide passes up one of these lines, each vat having a solution of milk of lime that is stronger than the preceding solution. The transfer is made by hooking the ends together when they go into the first vat, after which they are reeled to the next vat by the portable roller shown. This operation swells the hide, saponifies its greasy substances and dissolves the hair roots so that the hair can be removed easily. The hides being limed for the particular period required, usually 7 days, are now unhaired by a revolving slate-bladed cylinder that is passed over the hair or grain side of the hide; they are carried to this cylinder by a rubber roll and are pulled out by grip-rolls. The hair removed is a by-product that is sold to the manufacturers of hair-felt, cheap carpets, carpet padding and the like.

FLESHING

Some loose fat and fleshy material that is not suitable for making leather still remains on the hides; therefore, the hides are then run through the fleshing machine. This operation is practically the same as brushing, the flesh being removed by a rapidly revolving steel-bladed cylinder; a rubber roll carries the hides to this cylinder and grip-rolls pull it out as illustrated in Fig. 5. The material removed is commonly known as "fleshings" and is sold to glue manufacturers. After passing through the fleshing machine, the hides are put immediately into a "paddle," or vat containing clear water that is agitated by a paddle, and are washed thoroughly.

DELIMING

When washed, the hides are hauled from the foregoing paddle into another paddle containing a chemical bath. This operation is termed "bating" or "deliming." The nature of this process is partly chemical and partly bacterial; it is necessary to effect a complete removal

of the lime, to reduce the swelling and "plumping" that has occurred while in the lime, and to produce the requisite softness and pliability. This operation requires from 3 to 5 hr., according to the thickness of the hide; when completed the hides are again washed thoroughly and are then ready for the primary stages of tanning. This final washing completes all beamhouse operations. Then the hides are hung on a heavy wooden frame and transferred to the tan-yard.

Tanning

The frames upon which the hides are hung are lowered into tanning vats or "rockers" containing tan liquor, illustrated in Fig. 6. These frames are pivoted so that they can be kept in motion, thereby agitating the hides and the liquor constantly so as to effect a quick pene-

Fig. 4—Liming Is the Next Step in the Process
In the Liming or Unhairing Process the Hides Are Immersed in Milk of Lime To Swell the Hide, Saponify Its Greasy Matter and Dissolve the Hair Roots So That the Hair Can Be Removed Easily. This Operation Usually Requires 7 Days and the Hides Are Inspected Daily by Lifting Them Out of the Vat as Shown in the Background

tration of the tan liquor. The liquor in which the hides are suspended first is a very weak one in point of tanning strength but, each day for 8 consecutive days, the tanning strength is increased and, at the end of that period, the green hide becomes transformed into leather. This leather is not completely tanned, but is sufficiently so for its removal from the rockers and transference to the next operation. To eliminate excess moisture in the hides, they are now run through a wringing machine; this produces the desired condition by pressure and the absorption of moisture by heavy felt rolls.

After passing through the wringer, the hides are "prepared" and "stoned" or "set-out" before going to the splitting-machine. By "preparing" is meant the leveling, with a knife, of all scars, scratches and the like on the grain side of the hide. By "stoning" the ironing or flattening of wrinkles by a machine process is meant. The hides are now ready for "splitting."

Splitting

Splitting is one of the most important operations in the manufacture of upholstery leather. This work is done by a band or a belt-knife splitting-machine, such as is shown in Fig. 7. The knife in this machine is a double-bevelled endless-steel belt that passes around two pulley-wheels, it being horizontal in the part where it is used for splitting, as shown in Fig. 8. It travels with a continuous motion in one direction and is kept sharp by emery grinding-wheels that are fixed on the lower

Fig. 5—Fleshing and Unhairing the Hides
When the Milk of Lime Has Dissolved the Hair Roots, the Hide Is Taken to the Unhairing Machine Shown at the Right of the Illustration. Here a Revolving Slate-Bladed Cylinder Passes over the Hair or the Grain Side of the Hide and Removes the Hair Which Is a By-Product That Is Sold to Manufacturers of Hair Felt, Cheap Carpet, Carpet Padding and Similar Products. From the Unhairing Machine the Hide Is Taken to the Fleshing Machine at the Left Where Any Remaining Loose Fat and Fleshy Material That Are Not Suitable for Making Leather Are Removed by a Rapidly Revolving Steel-Bladed Cylinder. The Material Removed Is Sold to Glue Manufacturers

part of the machine; it is kept clean by passing through thick felt cleansers. The machine is capable of many adjustments so that the leather can be split to any desired thickness. The entire hide is fed to the machine,

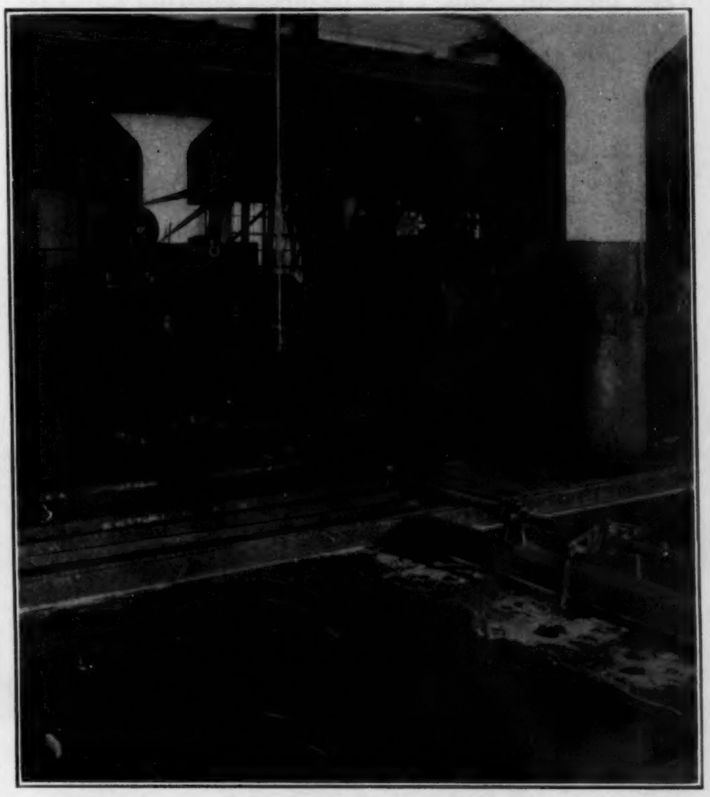

Fig. 6—The Tanning Vats
The Hides Are Hung on Pivoted Frames and Lowered into the Vats Containing the Tan Liquor Where They Are Kept in Motion To Effect a Quick Penetration of the Tan Liquor. After Remaining in a Vat for 8 Days, During Which Time the Strength of the Tan Liquor Is Increased Daily, the Green Hide Is Transformed into Leather

FIG. 7—SPLITTING THE HIDE
This is One of the Most Important Operations in the Manufacture of Upholstery Leather and Is Done by a Band or Belt Knife Splitting Machine That Consists of a Double-Bevelled Endless Steel-Belt Running over Two Pulleys. Emery Grinding-Wheels Fixed on the Lower Part of the Machine Keep the Knives Sharp and Thick Felt Cleansers through Which They Pass Keep Them Clean. The Whole Hide Is Fed In with the Grain Side Upward against the Sharp Edge of the Knife, the Grain Cut Passing over the Knife to the Operator, While the Remainder Passes under It and Falls to the Floor. Numerous Adjustments on the Machine Enable Practically Any Desired Thickness of Split To Be Obtained

grain upward, by two feed-rollers, against the sharp edge of the knife. The grain cut passes above the knife and the remaining portion beneath it. The grain cut is received by the operators, the remaining portion falls to the floor.

At this stage of the process, the hides are sorted. Then they are "split"; two methods, illustrated in Fig. 9, are in use. In the first, which is shown at the left, a split 1/64 in. thick is cut; this is termed a "buffing,"

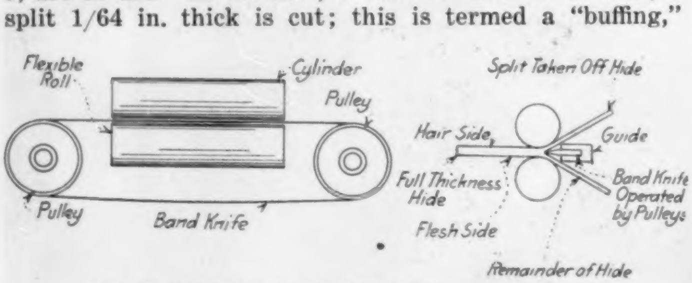

FIG. 8—THE ROLLS OF THE SPLITTING MACHINE
The Drawing at the Left Shows the Relative Position of the Band Knife, the Pulleys over Which It Runs Continuously in One Direction and the Feed Rolls. In the Drawing at the Right the Way in Which the Knife Splits the Hide Is Clearly Brought Out

which is sold and used for book bindings, wallets and the like.

The next split under the foregoing one is the "machine buff," so-called because the machine has removed the original surface by cutting the buffing already described. In the second method, which is illustrated at the right of Fig. 9, "full grain snuffed" is the first split of the hide. The remaining splits are the same for both methods.

The next cut under the full grain snuffed or under the machine buff is called the No. 1 split. This is the last cut that is used for automobile upholstery. Thus, only two splits per hide are available for automobile use. The No. 2 split and the "slab" are sold for insole leather, hand-bags and novelties or are made into chair seats and patent "dash-leather."

When splitting full-grain leather or "top grains," the grain-side is taken off first; then the remainder of the hide is put through the machine again for cutting the No. 1 split. The third pass through the machine cuts the No. 2 split and the "leveler" split. In splitting machine buffs, the leveler split is taken off first, then the buffing, the machine buff, the main split and the second split.

RE-TANNING

From the splitting room, the various grades of leather are taken to the re-tanning department. If the hides were thoroughly tanned in the rocker vats, it would be impossible to split them uniformly. The green layer in

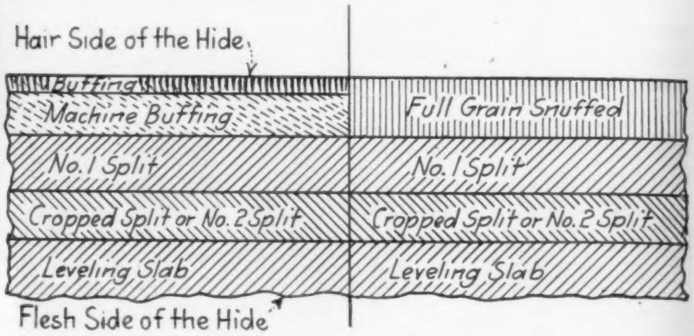

FIG. 9—TWO CONVENTIONAL WAYS OF SPLITTING HIDES
The Buffing Is Used for Bookbinding, Wallets and Other Leather Articles, While the Machine Buff and the No. 1 Split Are Used for Motor-Car Upholstery. The No. 2 Split and the Leveling Slab Are Sold for Insole Leather, Bags, Novelties and Similar Uses

the center of the hide-thickness acts as a yielding cushion for the knife; so, the re-tanning is simply a continuation of the process begun in the rocker vats. As the leather is now in thin sheets, the tanning liquor can penetrate

FIG. 10—FROM THE SPLITTING ROOM THE HIDES GO TO THE RE-TANNING DEPARTMENT
The Hides and the Splits Are Placed in Vats with a Paddle-Wheel Such as Is Shown in the Background at the Left To Agitate the Liquor. This Process Is a Continuation of the One Begun in the Tan-Yard Vats but Is Much Quicker Because the Leather Is Now in the Form of Thin Sheets. When the Re-tanning Process Is Complete the Hides Are Given a Coat of Cod Liver Oil and Degras Which Is Brushed into the Fibers of the Leather. The Top Grain Is Given an Additional Coat of Pure Cod Liver Oil on the Grain Side. This Oiling Operation Is Shown in the Foreground at the Left

more quickly than when the hide was in one piece; hence, re-tanning is a much faster process than tanning.

The hides and splits are re-tanned in vats having a paddle-wheel that agitates the liquor and keeps the hides floating in this moving liquor, as shown in Fig. 10. After remaining a few days in this re-tanning liquor, the now thoroughly tanned hides are taken out and washed in water or scoured on a machine; then they are ready for the sumac bath.

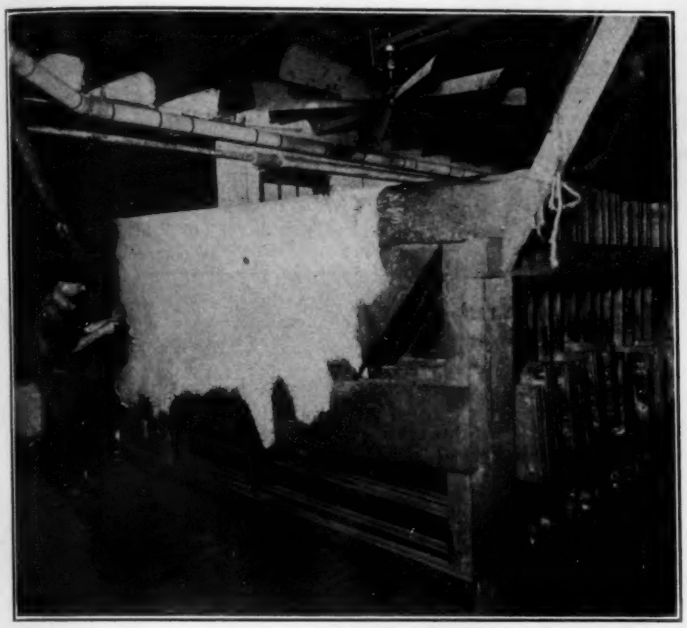

FIG. 11—WET TACKING HIDES

After the Hides Have Been Set Out and Stuffed, They Go to the Tacking Loft Where They Are Fastened on Large Wooden Frames and Thoroughly Stretched

FIG. 12—SHAVING AND BUFFING THE HIDE

Placing the Hide between a Fast Revolving Cylinder That Usually Is Composed of 16 Steel Blades and a Hard Rubber Roll Protected by a Leather Apron Shaves the Hide. The Men at the Right Are Shaving a Hide Which Really Means Taking Little More than a Fine Dust from the Grain Side. A Buffing Machine for the Production of Fine Leather Is in Operation at the Left

SUMAC TREATMENT

After a bath in warm sumac-solution that is paddled for a few hours, and after lying over night, the hides are allowed to drain. The sumac bath has the effect of clearing, bleaching and mellowing the hide and adds to the softening and the pliability that are so much desired for automobile upholstery. After draining, the hides are spread on long heavy hardwood tables and the sumac liquor is pressed out with steel "slickers." Then the

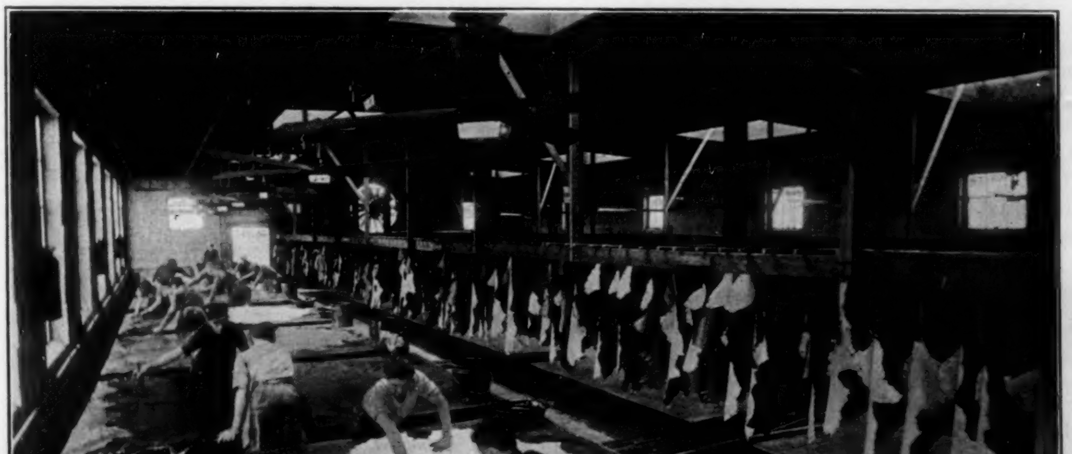

FIG. 13—DOPING OR FINISHING THE HIDE

In This Operation the Hides Are Spread Out on Tables and the Pyroxylin Finish That Is Composed of Gun-Cotton Solutions and Thinners Applied. The Hide in the Foreground Is Receiving the First Coat of Finish Which Is Applied with Brushes Resembling Those Used by Bootblacks. Subsequent Coats Are Applied by a Round Brush of Chinese Hog Bristles about 6 or 7 In. Long with a Wooden Peg or Dutchman in the Center. This Allows an Extra Quantity of Material To Be Carried and Also Gives a Good Spread to the Brush, a Very Essential Point in Making Good Finished Leather. Such a Brush Is Being Used at the Second Table. At the Right Can Be Seen Hides That Have Been Hung on Racks To Dry between the Applications of the Finish. On Account of the Heavy Fumes or Gases Generated While Applying the Coats Suction Fans Are Needed To Carry Off the Fumes. One of These Can Be Seen in the Wall in the Background

Fig. 14—Embossing the Leather

Presses Capable of Exerting a Pressure of 200 Tons and Equipped with Plates or Patterns of the Desired Kind Are Used for Imprinting the Grain or the Design on the Leather. These Plates Range from 22 x 24 to 26 x 48 In. in Size and Are Generally Electroplated and Nickeled

hides receive a coat of cod-liver oil and Degras, which is brushed into the fibers of the leather. The top grain gets an additional coat of pure cod-liver oil on the grain side, as shown at the left of Fig. 10.

Wet-Tacking

After the "setting-out" and "stuffing," the hides are taken to the tacking loft. Here they are tacked on large wooden frames and thoroughly stretched, as illustrated in Fig. 11. This loft is equipped with fans and, in combination with a little heat, they dry the leather overnight. The leather is now sorted into various grades; then it is shaved, softened and patched.

The shaving machine is illustrated in Fig. 12. The hides are placed between a fast revolving cylinder having, usually, 16 steel blades and a hard-rubber roll that are protected by a leather apron. In this operation little more than a fine dust is removed from the grain side of the hide, probably not more than 0.01 in. or one-half of 1/64 in. Softening is done by a machine that has a dull-edged knife coming between a cork and a rubber roll, or by tumbling in drums. Hides are then patched and ready for finishing. Russet leather receives its finishing coats by japanning, by doping or by a combination of both.

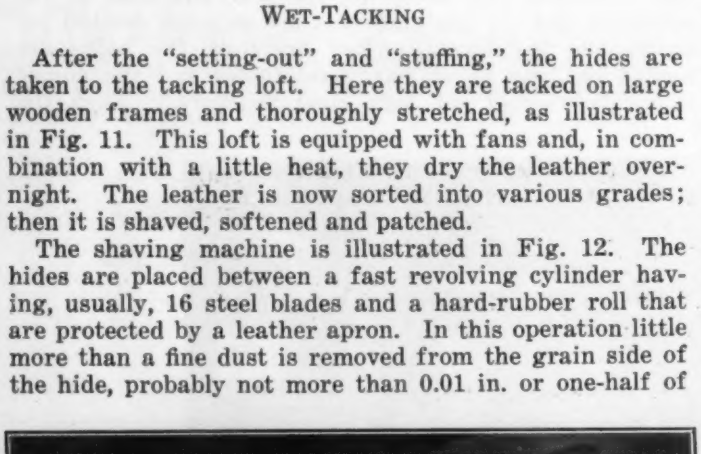

Fig. 15—Graining the Leather

Before the Advent of the Embossing Machine, the Grain Was Obtained by the Graining Board. Now the Grain Is "Applied" by the Embossing Machine and the Graining Board Is Used Principally To Soften or Bring the Grain Out More Prominently

Japanning

The hides are tacked on frames ranging from 8 x 9 ft. in dimensions up to 10 x 11½ ft. Linseed-oil, boiled to certain consistencies, comprises the coats used in japanning. The first or filler coats, usually three, are composed of linseed-oil that is boiled to the consistency of a jelly; it is known as "daub." These coats are applied by a steel blade that has a wooden handle and is known as a "slicker." Hides are well pumiced after the first and the second coatings. The fourth coat is a light application of heavy boiled oil known as "slicker varnish." Next are the finishing coats; they are composed chiefly of pigments, light boiled linseed-oil, turpentine, naphtha and dryers. All coats are dried in ovens at about 170 deg. fahr.

Fig. 16—The First Attempt To Measure the Strength of Leather

As an Olsen Testing-Machine Was Too Complex for the Tanner the Use of a Spring-Balance with the Hook Inserted in a Punched Hole in the Leather To Be Tested Was First Proposed. This Arrangement Was Not Satisfactory as a Variation of from 5 to 50 Lb. in the Same Hide Was Found

Doping

Pyroxylin finish is used for doping; it is composed of gun-cotton solutions and thinners. The hides are spread out on tables, as shown in Fig. 13. The first coat is applied with brushes resembling those used by bootblacks. Other coats are applied with "round brushes"; these are of Chinese hog bristles about 6 to 7 in. long and have a wooden peg or "dutchman" in the center that allows an extra quantity of material to be carried and also gives a spread to the brush, the latter being an essential point in making leather that has a good finish.

After each coat, the hides are hung on poles on a rack to dry. No extra amount of heat is necessary for drying these coats. Generally two coats per day are applied. In some instances finishing coats are applied with an air-brush. On account of the heavy fumes or gases generated while the coats are being applied, an arrangement of suction fans is necessary to carry off these fumes. For combination finish, the undercoats are of pyroxaline and the finishing coats of linseed-oil material; they are dried in ovens in the same manner as for full linseed-oil-finished leather.

Swelling, Embossing and Graining

Prior to embossing, the hides are subjected to a dampening or "swelling" process by semi-wet burlap or by humidifiers. For embossing or "plating," machines capable of exerting 200 tons pressure are used. They are equipped with plates or patterns of the desired kind and

imprint the grain or design on the leather. The machines, such as shown in Fig. 14, can accommodate plates of from 22 x 24 up to 26 x 48-in. size; generally, the plates are electrotyped and nickeled. Before the advent of the embossing machine the "grain" on "hand-buff" and "machine-buff" leather was obtained by a graining board, such as is shown in Fig. 15. This is known as the "natural grain" of the hide; but at present the grain is "applied" by the embossing machine, and the graining-board is used chiefly to soften or bring the grain up more prominently. Thence the hides are taken into the wareroom; there they are measured, stamped, cleaned, packed and shipped.

Detailed Control Essential

It will be noted from the foregoing that the details are many and that they must be fulfilled carefully. Hides must be washed properly, the lime and the tanning solutions must be of proper strength and be graded so that the green hide is not lime-burned, and none of the tanning liquors are to be wasted. The deliming, the bating and the fat-liquoring or oiling must be done with great care and accuracy or the dried split will be too hard and will not make a leather that is soft to the touch. Detailed descriptions of the processes are given in books that treat the subject.[3]

In nearly all cases these and other details are directed by men who have practical experience. They judge the amount and the strength of the process-materials to be used from the appearance of the finished leather as it comes through. In connection with much of the leather we now use, chemical control is practically unknown. In one tannery the tan-bark liquors were tested by tasting them. This reminded us of an early test of Babbitt metal by biting it and of a test of saw steel made by blowing the breath on the saw and noting the time required for evaporation of the moisture. However, these practical men have remarkable success in securing the good results they are seeking.

[3] See Practical Tanning, by Allen Rogers; also the Chemistry of Leather Manufacture, by John Arthur Wilson.

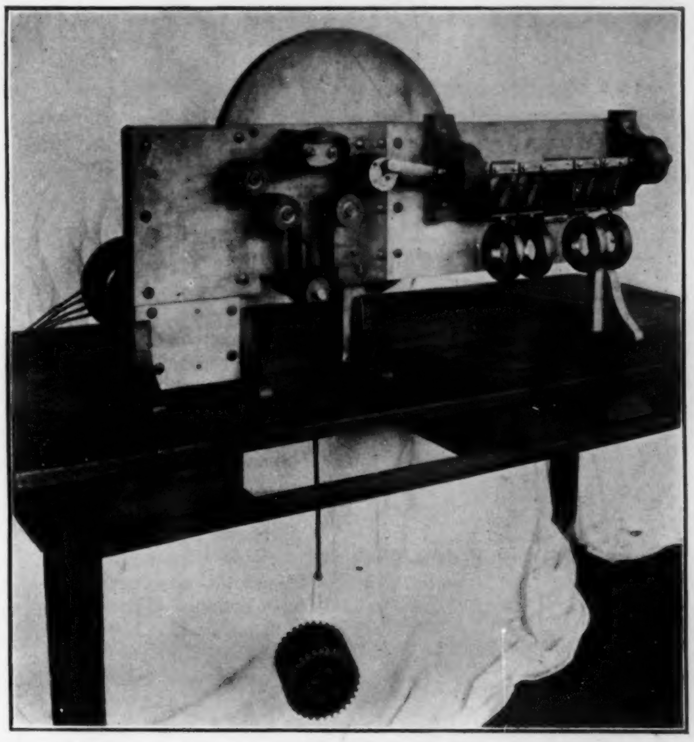

Fig. 18—Machine Developed To Test the Wearing Qualities of Leather

In This Machine a Continuous Belt Was Run Over Rolls. As a Result of Tests with This Machine the No. 1 Split Was Found To Possess the Greatest Resistance to Wear

Fig. 17—The Perkins Leather-Testing Machine

This Machine Has a Jaw 1 In. Wide That Grips a Specimen at Points 2 In. Apart. With This Machine Specimens Failed When from 50 to 350 Lb. of Tensile Stress Was Applied and Elongations in 2 In. of from 18 to 90 Per Cent Were Obtained

Leather Specification

In attempting to prepare a specification for leather, we found no information as to strength of leather and no means for testing for leather strength in a tannery. We found great differences in hides of apparently the same tannage. Variations of 400 per cent are common when hides are tested on a hand-operated Olsen testing-machine. Because an Olsen testing-machine is too complex for the tanner, we first proposed the use of a spring-balance, as shown in Fig. 16. The hook is inserted in a hole punched through the leather to be tested. This test showed variations of from 5 to 50 lb. in the same hide. Later we used a Scott testing-machine and also a Perkins tensile-strength testing-machine, such as is shown in Fig. 17. It has a jaw 3 in. wide and grips 2 in. apart. First a 2 x 6-in. and later a 3 x 6-in. specimen was used. This test showed failure on application of from 50 to 350 lb.; and elongations in 2 in. of from 18 to 90 per cent.

Strength of leather also varies with its thickness. The unit of measurement used is the same; it is 1/64 in. Finished leather should measure 3/64 in. thick, plus or minus one-half of 1/64 in. It is hoped that, when provided with means for testing the strength of leather, the tanner will be able to determine what details in his tannery cause tender or weak hides and unduly flanky leather. An excellent survey of leather strengths is

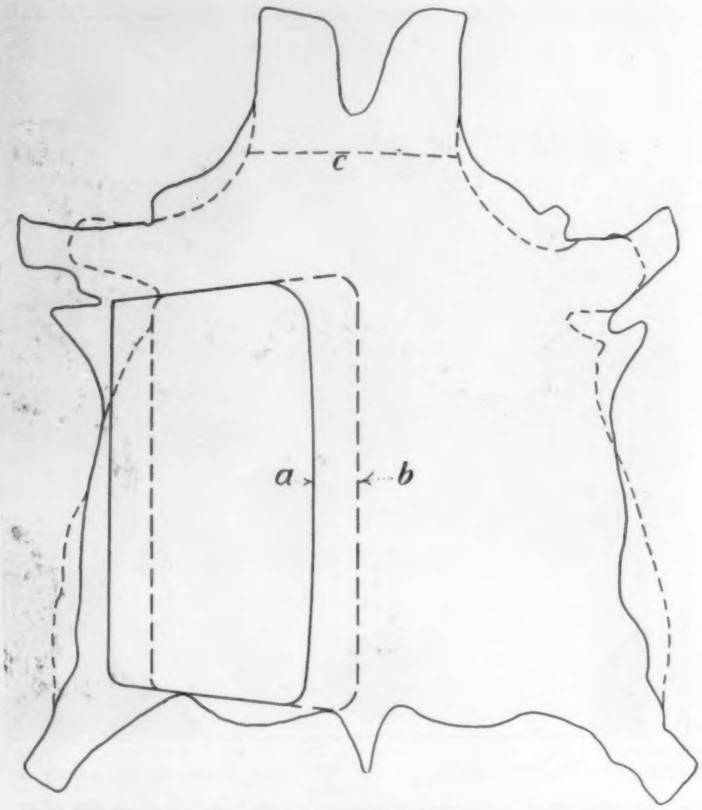

Fig. 19—How the Shape of the Hide Affects the Cutting Value

The Square Hide Shown by the Full Lines Gives the Minimum Waste, While the Triangular Hide Outlined by the Dash Lines Is Likely To Be Very Flanky. The Difference in the Cutting Value of the Two Hides Can Be Seen by Comparing the Seat Back *a* as Laid on the Square Hide with the Same Seat Back, Laid Out on a Triangular Hide and Represented by *b*. The Line of the Kosher Trim Is Indicated at *c*

found in letter circulars LC-97 and 106 of the Bureau of Standards.[4]

Generally speaking, grain leather snuffed, the highest-priced split, is the weakest; machine buff comes next and the No. 1 split, the lowest-priced, is the strongest. Also, in wear tests, such as running a continuous belt over rolls as in Fig. 18, or in a scuffing test, the No. 1 split is the best. As generally tanned, grain leather snuffed has the softest "feel." This feel, however, has been produced in the other splits by some tanners.

Patching Methods

Holes in a hide constitute an important matter for the tanner. When five or more holes exist in the same hide, it is classed as second-grade and brings a correspondingly lower price because of the waste in the cutting. The patching already referred to is intended mainly to keep the coating solution away from the reverse side. For this purpose tanners use paper, buffing a piece from the edge of the hide, and the like. The patch is pasted, glued or cemented. No definite standard of patching exists. With very few exceptions, patches cannot be safely cut into upholstery.

Because of the tremendous losses due to these holes, the committee proposed a method of patching that has since been perfected by the Radel Leather Mfg. Co. This method produces a patch that will not come off, cannot be seen from the finished side and is as strong and flexible as the hide itself. It is expected that this method will be included in the S. A. E. Specifications. It is anticipated that when this patch is in general use, savings of $400,000 per annum can be made by the tanner, and a still greater saving by the automobile builder.

Hide Shapes and Cutting Losses

The shape of a hide is important. In Fig. 19 the heavy line indicates a very good shape that gives a maximum cutting-value. The dash line shows a more triangular hide that is likely to be very flanky. A seat-back laid on the square hide is shown by the diagram *a*, and diagram *b* represents the same seat-back laid on a triangular hide. The kosher trim is indicated at *c*. Although the kosher trim removes from 1½ to 2 sq. ft. of the poorest leather in the hide, the tanner pays ½ cent per lb. less for this hide than for the other. This seems to be because the kosher trim usually yields splits of from 1 to 2 sq. ft. less area. The hides go through tannery piece work. The automobile builder wants large hides, and leather is sold on a footage basis. For the same reason, the tanner often leaves every possible bit of useless leather on the split, coating and finishing it at a high cost, only to have it thrown away by the automobile builder. We recommend using a dimension such as 6 ft. 2 in. or 6 ft. 6 in. behind the brisket, rather than to use area.

Hide shape, together with holes and flank, causes a variation of cutting loss from 18 to 35 per cent, or makes a difference of 10 cents per sq. ft. of useful leather when the price paid for the split is 30 cents per sq. ft. By utilizing the now almost useless head and leg parts of the hide, its shape can be corrected by filling-in; the flank can be reinforced; and the holes can be patched. This practice would save the automobile builder $2,000,000 per year, after allowing for the extra work of the tanner.

Details pertaining to the flexibility of leather and to finish and graining specifications have been left by the committee for action at a later date, because it seems advisable to concentrate attention now on part of a specification and put it into operation.

[4] See The Journal, October, 1923, p. 344.

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

RIDING-COMFORT FACTORS

IN view of the increased interest among engineers in the improvement of the riding qualities and comfort characteristics of passenger cars and buses the Society's Research Department felt that those interested would appreciate an opportunity for a general discussion of the important phases of the problem. Accordingly, arrangements were made for the symposium held at an informal supper in General Motors Building, Detroit, on Jan. 22, 1924. A brief account of the gathering, together with a list of those in attendance, was printed in the February issue of THE JOURNAL.

As a basis for discussion the following questions were proposed:

(1) What characteristics of the motion of a vehicle are especially disagreeable to the occupants? Are the actual motions, the accelerations, that is, the forces involved, or the rates of change of these forces, of major importance?

(2) Are persons equally sensitive to motions or forces in different directions, vertical, longitudinal or transverse, and, if not, which are more important?

(3) Are passengers sensitive to the motions of the vehicle body or only to those motions or forces transmitted through the upholstery, or partly to both?

(4) Do different people have radically different characteristics as regards discomfort, that is, are motions that are pleasing to some, uncomfortable to others?

(5) Is there any practicable means of gaging the degree of discomfort attendant on any particular type of vehicle performance?

The following outline of factors involved in the question of riding comfort was also presented for discussion:

FACTORS INVOLVED IN RIDING COMFORT

THE PASSENGER

Psychological and Physiological Reaction Factors
- (1) Direction of motion
  - (a) Displacements; vertical, longitudinal, and transverse
  - (b) Rotations; pitching and rolling about different axes
- (2) Type of motion
  - (a) Uniform velocity
  - (b) Acceleration
  - (c) Changing acceleration
  - (d) Duration and repetition
- (3) Noise
- (4) Vision
- (5) Air reaction
- (6) Temperature

Relative Effect of Above on Different Subjects

THE VEHICLE

Springing, Front and Rear
- (1) Spring-stiffness and initial deflection
- (2) Damping
- (3) Ratio of sprung and unsprung weight
- (4) Longitudinal and transverse flexibility
- (5) Inertia reactions within springs

Factors Bearing on Above
- (1) Type of spring
  - (a) Leaf type, semi-elliptic, three-quarter elliptic, full elliptic
  - (b) Coil type
- (2) Shape and size of spring members
- (3) Material and treatment
- (4) Elasticity and friction factors
  - (a) Lubrication
- (5) Accessory control by shock-absorbing devices
- (6) Periodicity ratio, front and rear
- (7) Spring attachments
  - (a) To axle
  - (b) To chassis

Tires, Front and Rear
- (1) Type
  - (a) Solid
  - (b) Cushion, so-called
  - (c) Pneumatic, low and high pressure
- (2) Size and relative proportions
  - (a) External dimensions and sections
- (3) Transverse stiffness
- (4) Material
- (5) Tread design
- (6) Inflation pressures
  - (a) Temperature effect

Wheels, Front and Rear
- (1) Type, construction
- (2) Weight
- (3) Rigidity

Chassis Frame
- (1) Weight
- (2) Stiffness in flexure and torsion
- (3) Vibration periods
- (4) Distribution of supporting points

The foregoing factors are determined by (a) Type of frame, (b) material, (c) dimensions and (d) wheelbase

Seating, Including Side and Back Supports
- (1) Number of seats
- (2) Location
- (3) Type
  - (a) Springing
  - (b) Upholstering
  - (c) Shape and tilt
  - (d) Material
- (4) Attachment

Body
- (1) Type of construction
- (2) Vision
- (3) Dimensions
- (4) Weight
- (5) Noise

Engine and Transmission
- (1) Vibrations, torsional and transverse
- (2) Torque reactions
- (3) Noise
- (4) Accelerations

Steering-Gear
- (1) Reversibility
- (2) Caster-action
- (3) Degree of play

(4) Reduction
(5) Location of wheel

Braking

(1) Smoothness of application
(2) Pedal-pressure and range of motion
(3) Equalization

The foregoing depend upon (*a*) type of brakes and connections, (*b*) the number of brakes and (*c*) their condition.

Heating and Ventilating

Lighting

(1) Interior
(2) Exterior

THE ROAD

(1) Obstructions, size and shape
(2) Condition of surface
(3) Material, type and workmanship

Regularity and Smoothness

Elasticity

(1) Material and type

Surface Contour

(1) Camber
(2) Banking

Curvature and Visibility

THE DISCUSSION

Dr. H. C. Dickinson, chairman, opened the discussion by outlining the general problem; he then called for comments from others in attendance.

H. M. Crane, president of the Society, called attention to the difficulty of choosing definite principles involved in riding comfort which could be made the subject of research. He said in part:

> It is obvious to me that the Society cannot undertake to develop anything or cooperate in the development of anything except possibly instruments for measurement in connection with research problems. But if we can bring out at a meeting like this some underlying principles such as the relations of sprung and unsprung weight or the relation of tire-size and spring-deflection rate per inch of deflection, or anything of that sort that affects riding, it is obviously a research question and well within the province of the Society to try to do, not in its own laboratory but with the assistance of other laboratories or with the Bureau of Standards or other Government activities. I want to emphasize the importance of keeping this thing, as far as the Society is concerned, to basic underlying principles involved, and not a question of accessories or anything like that to go with them. It is just what happens and where it happens.
>
> I think there is a very good reason to believe that the source of fatigue in riding is due to a rapid change of velocity, that is, rapid acceleration or deceleration in almost any direction. That may be over a long range or it may be of a very fine variety, and a rapid vibration of a small amount is often more trying than an occasional bump.
>
> I feel that the noise question goes with that; it undoubtedly increases a person's opinion of the bad riding of a car to hear the noise, because that emphasizes the smaller vibrations, but I am not at all sure that the noise itself being a high-speed vibration is not trying also in its own way.
>
> I believe all things stand together. For that reason I do not think that any measuring devices that do not attempt to measure the smaller vibrations, the very modest quantities, not only vertical but longitudinal and lateral, will get us what we are after, because it is the combination of all of them that makes the difference in the feeling of a car rolling over what we call a billiard table or rolling over smooth cobblestones. Smooth cobblestones well laid do not produce pitching in a car even with any ordinary spring equipment, but they do produce a vibration that is very trying if carried on for any considerable length of time.

T. J. Lítle, Jr., stated his belief that all passenger-car builders are at present interested in riding comfort. He enumerated balloon tires, shock-absorbers and new ideas in spring-suspensions among the factors that must be carefully studied by suitable methods of measurement. In this connection mention was made of a paper entitled, Spring-Movement and Vibration Study of Cars in Action,[1] prepared by Mr. Lítle.

Attention was called to the difficulties involved in depending upon human judgment alone in determining riding qualities of cars, especially when long periods of time elapse between comparisons. In attempting to overcome these difficulties, Mr. Lítle devised the instrument described in his paper and used it to record simultaneously the body vibrations and the spring-deflections. Notations were also made upon the record chart to indicate the impressions of the passengers.

In conclusion Mr. Lítle suggested that the Society's Research Department could very profitably cooperate with the different companies and act as a clearing house for the gathering and the disseminating of useful data on the subject of riding comfort.

J. E. Hale predicted that the question of improved riding comfort would be "played up" by automobile builders in the next few years; this he believed would be very favorably received by the public. Attention was called to the need for a scale of measurement of comfort in riding and also for suitable instruments to do the measuring.

Mr. Hale related some very interesting observations which showed that discomfort in riding is often attributable in large measure to rattles and other noises. For this reason the opinion of a deaf person is often valuable in comparing the comfort of different cars.

W. C. Keys described a method that he devised for studying the motion of different parts of a vehicle by mounting electric lights in various positions and photographing the paths of light during runs at night. Several interesting records were shown. As important factors in riding comfort Mr. Keys mentioned tire inflation-pressure, spring flexibility and lubrication, rebound control and flexibility of cushion-springs. He believed that certain of these factors should receive greater attention and study. The effect of accelerations was brought out by analogy with conditions on an elevator, where discomfort results from changes in velocity.

S. H. Woods reported that the company which he represents is working on the improvement of riding qualities of buses and has used the seismographic method of vibration-study for several years. He mentioned the value of the elastic mounting of springs in connection with shock insulation.

W. R. Strickland believed that the Research Department should assist in determining just what the passenger desires in the way of riding qualities. This he thought could be determined by laboratory tests on many persons by subjecting them to various types of motion simulating those experienced in riding. Mr. Strickland also discussed the influence of speed upon comfort and brought up an interesting aspect when he stated: "If you were to sit motionless for a day in a Pullman car at rest you would find it very uncomfortable."

Profs. R. Gesell and A. E. White, of the University of Michigan, were invited by the Research Department to be present and to discuss some of the physiological aspects of the riding-comfort problem. Professor Gesell stated that vibration may have an important effect upon physiological processes just as it has upon the physical properties of various materials. He mentioned the beneficial effect upon the body-tissues of massage and vibration caused by the pulse pressure. The fluctuation of this pressure has been found very important in connection with secretions of the body; when the pressure is held constant, the normal functioning of certain organs of secretion ceases.

It is known that eggs which are dormant can be started in development by vibration. On the other hand, it is also

[1] See THE JOURNAL, December, 1923, p. 445.

likely that development can be stopped by too much vibration.

In conclusion Professor Gesell asserted that suitable instruments for studying the effect of vibration could be devised very simply, but that a determination should first be made to indicate which types of vibration are beneficial and which types are not.

Professor White called attention to the importance of getting down to the basic principles involved in the riding-comfort problem; the fallibility of human judgment should be eliminated so far as possible by establishing the basic reasons for exhaustion or exhilaration of the passenger. This is a problem for the physiologist who would relate the vibrations with the fatigue produced.

J. W. Watson laid the blame for slight lack of comfort at the door of the springs, chiefly those at the front of the car. He felt, however, that present-day cars are as satisfactory in riding characteristics as we can reasonably expect them to be. More flexible front-springs were advocated.

On the subject of instruments Mr. Watson emphasized the importance of knowing not only the characteristics and the magnitude of the body motion but also the causes of the motion. Such an analysis would facilitate the application of suitable remedies.

Tore Franzen brought out a number of examples of deflection rates in front springs used on large-production cars of today. He stated that the trend in spring design is to follow rather well-defined empirical formulas in which the rate of deflection is determined by the load figure and a curve indicating the vibration period of the springs. The use of the slow moving-picture camera as a means of motion study was suggested. Referring to the question of noises in connection with riding comfort he believed that sounds like the squeaks from dry spring-shackles or rattling windows are annoying to most people. More harmonious sounds, like the hum of the engine, are less fatiguing. When leaf springs are the only means of suspension and when spring design has been governed accordingly, lubrication of the leaves should be avoided. If auxiliary devices, designed to dissipate energy, are used in connection with springs of the type described, lubrication is less harmful.

Herbert Chase called attention to the discomfort caused in certain cars by very rapid vibrations of small amplitude.

F. P. Herman reported that his company has just started some experimental work with slow motion-pictures; by this means it becomes possible to study the car and the passenger motions, and the road contour that causes the motions. It is also possible to determine accurately the speed of motion.

L. M. Stellman emphasized the importance of considering the speed-range of a car when designing the springs. In this the constructor should endeavor to make the car as comfortable to the passenger as possible throughout the chosen range, a requirement that apparently precludes the possibility of best riding-characteristics at other speeds.

A certain amount of side-sway or roll was believed by Mr. Stellman to be favorable to comfort in riding. He also felt that cushion-springs should be fairly stiff, thus reducing the motion between the passenger and the seat.

J. A. C. Warner suggested that most of the important phases of the problem could be studied conveniently in the laboratory where riding conditions could be accurately reproduced and repeated as desired. Such a method would also lend itself to satisfactory measurement of the conditions of test. It was believed that reasonably accurate indications of the effect of various motions upon the average individual could be gained by conducting and repeating tests on a great many persons.

C. M. Manly advocated close cooperation with the physiologists and psychologists and thought the latter should be carrying on their studies while automotive engineers are attacking the mechanical phases. Referring to Mr. Hale's observations, he suggested that in making psychological tests the noise problem be studied with subjects whose hearing would range from total deafness to very acute sensitiveness to sounds.

In conclusion Mr. Manly stated that one of the biggest problems awaiting satisfactory solution is that of instrumentation and the correct interpretation of results obtained.

H. L. Pope mentioned the importance of proper fit between the passenger and the seat.

J. C. Sproull in discussing the question of spring lubrication recalled an interesting incident relating to the damping of periodic vibrations by oil-filled dashpots.

Prof. E. H. Lockwood and L. B. Kimball of Sheffield Scientific School, Yale University, submitted the following interesting outline of their work on riding quality:

> The following discussion relates only to the effect of vertical motion on the riding qualities. Disagreeable characteristics are found at the two extremes: first, vertical accelerations of high frequency and small amplitude popularly known as jarring; and second, single accelerations of large magnitude produced by holes, obstacles and the like. Between these extremes lies a field of vertical accelerations of a gradual kind, often accompanied by a rhythmic up-and-down motion that is not objectionable.
>
> In designing an instrument for measuring the riding qualities of vehicles, the foregoing characteristics must be taken into account. The instrument should record fully the extreme accelerations referred to, but should respond less to the intermediate accelerations of the less objectionable kind. A form of seismograph that conforms fairly well to these conditions has been built at the Mason Laboratory for preliminary investigations referred to in this discussion.
>
> The principal part of the instrument is a seismograph pendulum suspended by a helical spring. Vertical motion of the pendulum is integrated by a friction ratchet, giving intermittent motion in one direction which is read on a revolution counter. A feature of importance is the use of a table under the pendulum, supporting a small portion of its weight. The supported pendulum differs in its action from a free pendulum, in that it does not get into oscillation. It responds freely to shocks or sharp accelerations but much less to easy up-and-down motions. The sensitiveness of the instrument is indicated by its ability to register and integrate vibrations from a four-cylinder engine while idling. The instruments used in road-testing have been rendered less sensitive by setting the table higher, so that more of the weight was supported.
>
> When about 2 per cent of the pendulum weight is supported by the table, the instrument will not register in a railroad coach on a smooth road-bed, but will register in an automobile on the smoothest road found thus far.
>
> In preliminary trials of the instrument it was carried in a number of cars, which were run over a stretch of road near New Haven for comparative readings. Runs were made at different times, but under identical conditions as nearly as possible, that is, with the same driver at the same speed with the same inflation and the like. Inspection of the records shows that the instrument readings vary for different cars, also for the two kinds of road.
>
> It has not yet been demonstrated that the instrument readings correctly interpret the disagreeable features of vertical motion to the occupants of the vehicle. It appears, however, that the instrument is at least an approximation to what is wanted and that its readings are easily made and understood.

PUBLICATIONS

The following references to publications relating to riding-comfort factors may be of interest:

Cantilever Springs, by John G. Utz; TRANSACTIONS, vol. 10, part 1, p. 172

Scientific Chassis Construction, by A. P. Brush; TRANSACTIONS, vol. 10, part 2, p. 354

(Concluded on p. 341)

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

COLOR CODE FOR CABLE PROPOSED

All Principal Electrical Circuits to Be Identified to Facilitate Service

A color code for the identification of the principal electrical circuits in passenger cars and motor trucks has been proposed by the Automobile Wiring Subdivision of the Electrical Equipment Division, of which W. S. Haggott is chairman. The code proposed is as follows:

(1) Solid Red: For circuits connecting the ammeter, the generator, the battery and the lighting switch, but not for the starting-motor cables
(2) Solid Black: For the bright head-lamp wires
(3) Solid Brown: For auxiliary head-lamp wires
(4) Black, with Three Parallel Green Tracers: For tail-lamp wires
(5) Solid Yellow: For side-lamp wires
(6) Black, with Three Parallel Red Tracers: For horn wires
(7) Yellow, with Three Parallel Green Tracers: For low-tension ignition wire
(8) Solid Green: For all ground connections, but not for starting-motor cables
(9) Yellow, with Three Parallel Red Tracers: For wire from the source of current to the signal-lamp switch and to the signal-lamps

The code proposed represents the opinion of the Subdivision and is subject to constructive criticism. As the report will be acted upon at the next meeting of the Electrical Equipment Division, changes considered necessary should be brought to the attention of the Standards Department at an early date. It should be recognized that the proposed code is intended as a general standard for the industry to work toward. Its immediate adoption is not feasible in all cases, but the advantage of having it adopted in all future production is self-evident when the time required under present conditions in tracing out circuits in electrical repair work is considered.

At a joint service meeting held by the National Automobile Chamber of Commerce and the Society of Automotive Engineers in Dayton in November, 1923, a paper was submitted by P. J. Durham on Electric Repair Problems Encountered in the Field. In this paper,[1] which was printed in the February issue of THE JOURNAL, Mr. Durham stated that

> The suggestion has been made that a standard code of colors be adopted for the wiring of different circuits for the electrical system. This method was in practice 12 or 15 years ago and, although the idea is not new, it certainly would be a marked progression in the direction of rendering better service to a car-owner if generally adopted in actual practice. It would lessen to an amazing degree the time necessary to trace out or test out the various wires. Anyone who has tried to trace a circuit in a maze of wires under the average instrument-board would appreciate such a standard color-code.

At a meeting of the Buffalo Section in March, 1922, W. S. Haggott stated in a paper[2] on Electrical Wiring for Automobiles that

> I would like to suggest that some effort be made to develop a standard color-scheme for various circuits. For example, every car has a wire running from the battery or starting-switch to the ammeter. Is there any reason why a certain definite color could not be assigned to this and other wires that are common to all cars, and a standard wiring color-scheme among car builders attained? This would be of great value to the car driver and repair-man and provide a uniformity that would be helpful to the industry in many ways

That the use of colored cable is practicable is evidenced by the fact that the Subdivision making the proposal includes representatives of the Remy Electric Co., the Boston Insulated Wire & Cable Co. and the Packard Electric Co., as well as representatives of several automobile builders. The proposed code is to be submitted to the engineering departments of passenger-car, motor-truck and electric-apparatus manufacturers for comment. The comments submitted will receive the careful consideration of the Subdivision members in order that the proposed code may be revised so as to meet more nearly the requirements of the automotive industry.

[1] See THE JOURNAL, February, 1924, p. 163.
[2] See THE JOURNAL, November, 1922, p. 431.

WIRE-CLOTH STANDARD REVISED

Slight Changes Made Although Original Report Met with General Approval

The proposed standard for wire cloth, which was printed on p. 503 of the December, 1923, issue of THE JOURNAL, met with the general approval of the engineering departments of passenger-car and motor-truck builders. The proposal was revised in some particulars, however, as the result of certain constructive comments. The revised report is given herewith for final study before the action at the Standards Committee Meeting next June.

Shipment of wire cloth direct from the manufacturer's stock, quicker deliveries and an increase in the sources of supplies are cited as the probable results of the adoption of the proposed standard in future practice. It has been suggested that the number of meshes might be reduced but, as differences of opinion are bound to occur as to which should be eliminated and as all of the sizes listed are now in production, it was not considered advisable to limit the list further. The diameter of the wire is specified in thousandths of an inch. This has been done to obviate the confusion that has arisen owing to the fact that various manufacturers of wire cloth use various gages to indicate the wire diameter. The diameter tolerances proposed are such that the actual diameters used by the various manufacturers fall within the various diameter-ranges listed.

Proposed S. A. E. Standard for Wire-Cloth

Mesh	Diameter of Wire, In.	Size of Opening, In.	Mesh	Diameter of Wire, In.	Size of Opening, In.
8	0.028	0.097	45	0.0095	0.0130
10	0.025	0.075	50	0.0090	0.0110
12	0.023	0.060	60	0.0080	0.0090
14	0.020	0.051	70	0.0070	0.0073
16	0.018	0.044	80	0.0060	0.0068
20	0.016	0.034	90	0.0050	0.0059
24	0.015	0.027	100	0.0045	0.0055
30	0.013	0.021	120	0.0040	0.0043
35	0.011	0.018	150	0.0030	0.0037
40	0.010	0.015	200	0.0021	0.0029

Mesh denotes the number of openings per inch.

The weave shall be what is known as "Plain," except that in meshes 80 and finer, "Twilled" weave may be used.

Double-crimped wire shall be used and woven so as to give square openings.

The accuracy of spacing wires shall be such as to give openings within 10 per cent, plus or minus, of the openings specified.

The variation in the diameter of the wire shall not exceed the following limits in inches:

Up to and including 16 mesh	0.0030
From 20 to 50 mesh	0.0020
From 60 to 100 mesh	0.0015
Above 100 mesh	0.0010

The material shall be specified by the purchaser, taking account of the fact that at present manufacturers of wire-cloth stock these meshes in steel and brass up to about 80 mesh; above this it is common practice to supply phosphor-bronze and monel-metal.

200 SERIES INCORRECTLY DESIGNED

Widths of First Six Sizes of Wide-Type Ball Bearings To Be Increased

F. G. Hughes, of the New Departure Mfg. Co., has, as a result of an investigation covering several years, proposed increases in the widths of bearings Nos. 200 to 205 inclusive in the present S. A. E. Standard for Wide-Type Annular Ball Bearings, p. C31 of the S. A. E. HANDBOOK. The present and proposed widths are as follows:

Bearing No.	Present Width, In.	Proposed New Widths, In.
200	½	9/16
201	½	5/8
202	½	5/8
203	½	11/16
204	¾	13/16
205	¾	13/16

The reasons for proposing the changes were outlined as follows in the report submitted by Mr. Hughes, which will be acted upon at the next meeting of the Ball and Roller Bearings Division:

(1) The narrower widths do not allow sufficient center-to-center distance between the two rows of balls to accommodate a separator of sufficient strength; that is, the space between the two rows of balls does not allow sufficient thickness of material, in view of the fact that it is absolutely necessary that the two rows be controlled by separators that are entirely independent of each other

(2) In some sizes the width does not permit a race section capable of withstanding the loads that the balls are capable of sustaining and, therefore, it is impossible to obtain the maximum carrying-capacity of the bearings

(3) In some cases the increase in race section allows an increase in the ball diameter, thereby increasing the carrying capacity of the bearing

BOLT AND NUT STANDARDIZATION

Farm Equipment Manufacturers and Sectional Committee Agree on Program

At a conference in the City of Washington, on Feb. 19 and 20, called by the Division of Simplified Practice of the Department of Commerce at the request of the National Association of Farm Equipment Manufacturers for the purpose of adopting its proposed standards for plow and carriage bolts and machine bolts and nuts, a long step forward was taken in the program of standardizing these products which has also been under way in the Sectional Committee on Bolt, Nut and Rivet Proportions that is sponsored by the American Society of Mechanical Engineers and the Society of Automotive Engineers. Although up to the time of the conference the Sectional Committee and the National Association of Farm Equipment Manufacturers have been working on this project separately, the most important result of the meeting was arrangement whereby the Association would be represented by O. B. Zimmerman on the Sectional Committee and cooperate in formulating a single group of standards.

Secretary Herbert Hoover in addressing the conference stated that as little prospect of a reduction of costs in labor and material is probable for some time to come, the simplification work inaugurated and conducted by the Division of Simplified Practice opens the way for associated corporations to cooperate effectively toward the reduction of costs by the elimination of unnecessary varieties of product. Referring especially to this conference, he continued by saying that the cooperation of the technical and trade associations representing the interests concerned, especially the implement associations, will tend to raise them in the esteem of the farmers by making it possible to show them that the industries the associations represent are trying to reduce the cost of their products and that such projects when once well started have a more far-reaching effect than is often anticipated.

The conference spent most of its time in considering the details of the proposals, making such modifications in them as it is expected will be acceptable to the bolt and nut manufacturers and to all classes of consumers. The National Association of Farm Equipment Manufacturers proposal for plow bolts was accepted practically as submitted and will eliminate 3 of the 7 types at present in most general use although 10 types have been available. The Sectional Committee proposal on carriage bolts was accepted with some modifications in place of the agricultural equipment proposal that differed principally in the head and the square-neck dimensions. After considerable discussion as to including both short and long-neck bolts it was decided to recommend only one type of long-neck bolts. It was agreed that the distance across the flats of both square and hexagon-head machine bolts shall be 1½ times the bolt diameter with slight variations to meet a series of wrench openings for bolts of from ¼ to 1-in. sizes which will reduce the number of wrench openings by approximately 50 per cent. Similar action was taken with regard to square and hexagon-nut sizes except that they will be smaller by approximately 1/16 in. than the head dimensions for corresponding bolts.

All of the proposed standards will be complete in detail dimensions and tolerances, the threads in all cases being specified in accordance with the Free Fit Class as given in the reports of the National Screw Thread Commission and the Sectional Committee on Screw Threads. The above reports, which, with the exception of plow bolts, have been issued tentatively by Sub-Committees 2 and 5 of the Sectional Committee on Bolt, Nut and Rivet Proportions, will be revised as soon as possible in accordance with the recommendations of the conference for circularizing and approval by the Sectional Committee, after which they will be submitted to the sponsor Societies for final approval. The revised reports will include the recommended plow bolts.

At the suggestion of William A. Durgin, chief of the Division of Simplified Practice, Department of Commerce, who stated that it is necessary for the Division to publish a date on which the standard will become effective, the manufacturers and users present agreed to make the new standard effective in all new production beginning Jan. 1, 1925, and that they will endeavor to use up all non-standard stocks now on hand by Jan. 1, 1926. It was stated that in several cases many thousands of tons of raw materials are now on hand and a great many tools that cannot be scrapped for some time to come are in use. It is evident also that the users cannot be expected to modify their products in accordance with the new standards until they can do so economically.

At the general conferences, Mr. Durgin presided on the

19th and Secretary Hoover and Mr. Durgin on the 20th. Prof. A. E. Norton, chairman of the Sectional Committee on Bolt, Nut and Rivet Proportions, presided at all conference committee sessions. Among the organizations represented were American Engineering Standards Committee; American Society of Mechanical Engineers; Bureau of Foreign and Domestic Commerce; Bureau of Public Roads; Chamber of Commerce of the United States of America; Copper and Brass Research Association; Division of Building and Housing, Department of Commerce; *Hardware Age*; National Association of Farm Equipment Manufacturers; National Screw Thread Commission; Naval Gun Factory; Navy Department; Quartermaster's Corps, U. S. A.; Railway Car Manufacturers Association; Society of Automotive Engineers; Southern Hardware Jobbers Association; War Department, and a number of bolt and nut manufacturers.

SHEET STEEL PROBLEMS IMPORTANT

Iron and Steel Division Members Report Progress at Detroit Meeting

Progress on several subjects before the Iron and Steel Division was reported at a meeting held on Jan. 23, in Detroit, during the week of the Annual Meeting of the Society. Among the subjects considered were chemical compositions of chromium-silico-manganese, nickel-chromium and molybdenum steels, heat-treatments and sheet steel.

It was reported that the Subcommittee on Testing Sheet Steel had not made as much progress as was anticipated and that it might be well for the testing to be undertaken by the members of the entire Sheet Steel Subdivision. It was felt that results might be obtained in a shorter space of time if this were done and that it would distribute the expense of the work over a greater number of members.

At the Annual Meeting of the American Society for Steel Treating in October, 1923, a paper was submitted by H. M. Williams covering the problems encountered in developing sheet-steel specifications. Mr. Williams is a member of the Sheet Steel Subdivision and a metallurgist associated with the General Motors Research Corporation. The larger part of his paper, published in the *Transactions of the American Society for Steel Treating*, is given hereinafter:

Automobile Sheet Steel Specifications

The development of specifications for the inspection and test of automobile sheets is occupying the attention of many metallurgists and engineers. The demand for this class of steel has at least equalled the supply, and this situation has been a large factor in the postponement of standardization of this important automotive structural material. Very great losses in unusable stampings and in labor to repair defective ones have resulted from faulty or unsuitable material, difficult forms and improper die construction. Frequently, a new die will not produce a perfect stamping for weeks after it is put into commission. Body engineers design parts that are very difficult to develop and the die engineer is not consulted until the design has been approved. It is then a question of finding a quality of sheet that will produce the desired part in a certain die, which often makes it necessary for some sheet mill to produce a new quality of sheet. At the present time, one sheet mill is producing over 50 different kinds of sheets varying in surface finish and temper. It is evident that this condition of affairs results in a great economic loss to both producers and consumers. Only the full cooperation of the sheet mills and the automotive body and parts makers can remedy this condition and standardize sheets, design and die construction.

The logical procedure as a first step in the development of specifications is to standardize on a few sheets representing the surface finishes required for the various methods of finishing and then produce these sheets in a limited number of tempers. Temper refers to the ability of the sheet to form, such as is indicated by deep drawing or extra deep drawing, and not to the carbon or alloy-content of the sheet. Die construction must permit of sufficient adjustment to correct for permissible leeway in the physical properties of each temper. Whenever a new part is to be produced, the steel can be readily selected first from the standpoint of finish and the temper then selected by actual tryout of sheets. A standard nomenclature will eliminate many trade-names that have been given to sheets by the manufacturers; the same name often referring to sheets of different characteristics is produced by different mills. If such a classification could be made, every one interested would soon be familiar with surface finish and temper, and sheets could be readily substituted, from plant to plant, or job to job.

The question of the gage of sheets should have consideration. Instead of using gage numbers, the thickness should be specified in thousandths of an inch, with permissible tolerances within reasonable limits. The mills prefer to roll steel to decimal rather than to gage numbers. The thickness of sheets is very important on account of its effect in the dies; before the stampings can be made, it is often necessary for the sheet metal departments to separate the sheets into piles according to their thicknesses. The thickness tolerances on the sheets are very often greater than can be taken care of by the dies without considerable adjustment.

The difficulties encountered in the production and the utilization of sheets are numerous and varied. One of the sheet mills has a standard form of data sheet that analyzes rejections of pickled sheets. On this form, 6 defects are chargeable to sheet bars, 17 to hot-rolling, 4 to pickling, 8 to cold-rolling and 3 to annealing, making a grand total of 38 causes for rejection. Even after a sheet successfully passes this ordeal, it may give trouble in the stamping operation due to forming qualities, poor surface after forming, pulling coarse, stretcher strains and the like.

Forming qualities are dependent to some extent on the surface finish, and particularly on the temper, which is one of the most difficult properties to determine. Forming qualities are determined by actual tests in the dies, this being the only reliable method. Such indications as color, gloss, bending a corner of the sheet between thumb and finger, doubling the entire sheet, bending test-samples over on themselves both ways of the grain, and tensile-strength and elongation and cupping tests are also used with varying degrees of reliability.

Surface inspection is largely a matter of good judgment. It would pay every inspection department to send a man to the mills and cooperate in the mill inspection. Many times sheets are thrown out at the mill for defects that may be discarded in cutting out the blank from which the stamping is formed. Personal contact and a knowledge of just how certain defects are produced will be very enlightening to any sheet inspector.

Stretcher strains are the most undesirable defects to which all sheet is more or less subject. This defect produces the effect of lines and designs in intaglio and ofttimes is too deep to be removed by grinding. This phenomenon is intimately connected with slip of the individual grains over or past one another. The remedy consists in passing the sheet through cold rolls or a roller leveler. The stampings should be made as soon as possible after the sheets have been given this treatment; some shops are laid out to pass the sheets through a roller leveler and immediately into the forming press. One authority states that after the sheet is given the roller-leveler treatment, it is in a plastic condition which may set in a few hours or over-night, and unless the stamping is formed before this set takes place, stretcher strains will be produced the same as before.

Grain size is a very important factor in the forming quality of the sheet. The grain size is governed to a

large extent by the amount of rolling and the annealing temperature. This has been pointed out in detail in a number of published articles.

SCALE IS TROUBLESOME

Scale is the cause of much trouble as it must be removed before finishing. Scale is also very hard on the dies on account of its abrasive nature. Dies used in forming scaly material are often fitted with replaceable hardened steel inserts that are renewed when worn. The scale referred to here is heavy scale and should be carefully differentiated from the very light thin scale, or better, oxide, that is purposely produced on high-grade sheets. This type of oxide is of microscopic thickness and is not broken away in forming. This oxide assists in preventing the sheets from rusting during transportation and storage. On parts that are finished by enameling it is very important that this oxide be not heavy enough to produce a dull finish.

SECONDS

"Seconds" are a source of much dispute. It is customary for the manufacturers to include up to 15 per cent of seconds in shipments of high-grade automobile sheets. These sheets are often a dead loss to the body or parts maker, unless some other stampings are being made which will permit their use. Often the seconds must be used where a cheaper material would have been just as satisfactory.

The Sheet Steel Testing Subcommittee of the Iron and Steel Division of the Society of Automotive Engineers has adopted a program for the investigation of automobile sheet steel. The object is to accumulate data that can later be incorporated into a standard specification. This program provides for the following tests which deal with the determination of forming qualities and temper: Tensile-strength and elongation, Olsen cup-test, Ericson cup-test, Rockwell hardness-test, scleroscope hardness-test, microscopic and macroscopic examination, chemical analyses and bend test.

TUBE FITTINGS AGAIN REVISED

Imperial Brass Mfg. Co. to Grant Manufacturing Rights for Compression-Type Fittings

As a result of constructive criticisms brought out at a special meeting of the Parts and Fittings Division in Detroit on the day preceding the Standards Committee Meeting, the Division's report on compression-type fuel and lubrication tube-fittings, which had been included in its report and printed on p. 47 of the January, 1924, issue of THE JOURNAL, was withheld in order that the industry might have an opportunity to comment on the revisions made at the meeting and to suggest any further revisions.

As the meeting in Detroit was called especially to consider the recommendation for tube fittings, representatives of many of the fitting manufacturers were present. The principal changes proposed in the recommendation as printed in the January issue of THE JOURNAL were as follows:

(1) To omit the length of thread *J* in the table for collars, nuts and straight threaded-ends

(2) To specify the thread length on the elbows, tees and unions

(3) To indicate a 45-deg. chamfer on the outside of both ends of the nut

(4) To change the length of the sleeve *B* to ¼ in. for the 5/16 and ⅜-in. tube diameters

(5) To substitute the following dimensions for the sleeve bore with tolerances of plus and minus 0.002 in., in place of the maximum and minimum limits specified:

Tubing Diameter, In.	Sleeve Bore, In.
1/8	0.130
3/16	0.193
1/4	0.257
5/16	0.323
3/8	0.386
1/2	0.515

(6) To change the length of the nut for the ⅛, 3/16 and ¼-in. tube diameters to ⅜, 13/32 and 7/16 in. respectively

(7) To specify that the screw-thread fits and tolerances for the fittings and the nut shall conform to the S. A. E. Standard Free Fit for screws and nuts in the fine-thread series

It was understood that the revised recommendation would be submitted to fitting manufacturers and users for further study prior to the next meeting of the Standards Committee.

The offer of the Imperial Brass Mfg. Co. to grant a license to manufacture, use and sell the type of fitting manufactured for use in the automotive industry to any corporation or individual specified by the Society for consideration of $1 to clarify the patent situation was also discussed. It is expected that this phase of the situation will be referred to the National Automobile Chamber of Commerce.

RESEARCH TOPICS AND SUGGESTIONS

(*Concluded from p. 337*)

Dynamics of Vehicle Suspensions, by Dr. Benjamin Liebowitz; TRANSACTIONS, vol. 11, part 2, p. 186

Remarks on the Dynamics of the Automobile, by N. W. Akimoff; TRANSACTIONS, vol. 12, part 1, p. 142

Spring Design for Easy Riding, by Walter C. Keys; THE JOURNAL, December, 1917, p. 366

Shock-Absorbers for Easy Riding, by M. H. Landis; THE JOURNAL, June, 1918, p. 424

Theory of Plate Springs, by David Landau and P. H. Parr; THE JOURNAL, February, 1919, p. 67, and June, 1919, p. 467

A Study of Road-Impact and Spring and Tire Deflection, by A. F. Masury;. THE JOURNAL, July, 1920, p. 96

Springs and Spring-Suspensions, by E. Favary; TRANSACTIONS, vol. 15, part 1, p. 143

The Measurement of Vehicle Vibrations, by Dr. Benjamin Liebowitz; TRANSACTIONS, vol. 15, part 1, p. 258

A New Principle of Engine Suspension, by S. E. Slocum; THE JOURNAL, January, 1921, p 54

Holding the Road, by J. L. Napier; *Automobile Engineer*, August, 1921, p. 266

New System of Spring-Suspension for Automotive Vehicles, by H. M. Crane; THE JOURNAL, June, 1922, p. 463

Springing and Comfort; THE JOURNAL, December, 1922, p. 553

Notes on Spring Action, by V. H. Gottschalk; THE JOURNAL, March, 1923, p. 312

Principles of Vehicle Suspension, by H. S. Rowell; *Automobile Engineer*, April, 1923, p. 118

Spring Movement and Vibration Study of Cars in Action, by T. J. Litle, Jr.; THE JOURNAL, December, 1923, p. 445

Air-Riding Comfort, by J. J. McElroy; THE JOURNAL, January, 1924, p. 93, and February, 1924, p. 257

New Quantitative Method of Measuring the Riding Comfort of Automobiles, by F. H. Norton; THE JOURNAL February, 1924, p. 136

MEETINGS OF THE SOCIETY

ANNUAL MEETING IN DETROIT AGAIN

Tractor, Production, Transport, Aero and Other Meeting Plans Also Announced

Detroit will again play host to the Annual Meeting in 1925. This and many other important decisions are announced by the Meetings Committee, which has completed a program of national meetings of the Society for the entire administrative year. The complete success of the recent Detroit meeting left no doubt as to the best course to follow next year. The 1925 Annual Meeting will be held during the week in January just preceding the Chicago Show. Headquarters and all sessions will be held in the General Motors Building. The Carnival will be repeated as the social feature of the Detroit Meeting.

Tractor Meeting at Chicago

H. O. K. Meister

Chicago has again been chosen as the site of the Tractor Meeting. The dates have not been selected definitely, but it is proposed to combine the meeting with that of the National Association of Farm Equipment Manufacturers some time in April. The meeting will last a full day, there being a morning and an afternoon technical session with an informal luncheon at noon. One of the sessions will be devoted to papers and discussion on the agricultural uses of the tractor, presumably touching upon the general-purpose type. The other session will include papers on the use of tractors for road-building, contracting and industrial applications. Efforts are being made to secure an eminent agricultural economist to address the luncheon. H. O. K. Meister is assisting the Meetings Committee in the procurement of papers and in the arrangements for the Tractor Meeting.

Automotive Transportation Meeting

Engineering phases of the design, operation and maintenance of motor vehicles used in commercial transportation will be treated in a 2-day meeting of the Society which will be held in New York City in September. Three distinct types of commercial vehicles will be discussed; the motor truck, the motorbus and the rail-car. In addition to three professional sessions, there will be a Transportation Dinner held jointly with the New York Railroad Club and organized visits to motor-truck and motorbus terminals or projects. This meeting is being organized by F. C. Horner of the Meetings Committee.

Exhibit Part of Production Meeting

If present plans materialize, an exhibition of machine tools and production equipment will be held in conjunction with the national Production Meeting of the Society next fall. This meeting and exhibit will be held in the General Motors Building at Detroit, Oct. 21 to 25. It is probable that the sessions themselves will be grouped into 2 days of this period, the remainder of the time being given over to the exhibition, factory visits and the convention of the National Machine Tool Builders' Association.

The purpose of the exhibition is purely an educational one. There have been many requests that the Society sponsor such an exhibition for the convenience of its members who come to the Production Meeting anxious to hear about, see and inspect new manufacturing equipment, processes and methods. It is hoped to attract to the exhibit those manufacturers who wish to display new tools, conveying machinery, painting and enameling equipment, labor-saving devices, materials and in fact anything that will appeal to the automotive production executives. Efforts will be made to have most of the exhibits under power or otherwise demonstrated.

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Hotel Monmouth, Spring Lake, N. J.
The Sessions of the 1924 Semi-Annual Meeting of the Society Will Be Held Here on June 24 to 27

Programs for the Production Meeting sessions are now being formulated. Those desiring representation should submit outlines of their papers to the office of the Society at this time. K. L. Herrmann of the Meetings Committee is directing the plans for the sessions.

Aeronautic Meeting in Dayton

Aeronautical engineering sessions will be held in Dayton at the time of the International Air Meet and Pulitzer Race there next October. It is felt that this arrangement will insure a representative attendance of those members actively engaged in the aeronautical industry as well as those whose interest in the development of commercial aviation is keen. Arrangements for this meeting are in charge of H. L. Pope of the Meetings Committee. Definite dates will be announced in a subsequent issue of The Journal.

Service Meeting at Cleveland

The annual Service Meeting will be held in Cleveland Nov. 25 and 26. It will follow the plan that proved so successful in Dayton last fall, being arranged as a joint meeting of our own organization and the factory service managers of the National Automobile Chamber of Commerce. There will be three sessions, all devoted to discussions of the engineering problems met in maintenance and repair work on automotive vehicles of all types.

The annual dinner will be held in New York City as in years past. It is scheduled for Thursday evening of Automobile Show Week, January, 1925.

A meeting on motorboat subjects will be arranged during the week of the national Motorboat Show, which is expected to be run coincident with the Automobile Show in New York City, next January.

MILWAUKEE PETITIONS FOR SECTION

Members of the Society in the Milwaukee district have forwarded a petition to the Council to authorize the formation of a probationary Section in Milwaukee, to be known as the Milwaukee Section. As has been noted in these columns for the past few months, the Milwaukee members have been holding regular meetings which have been enthusiastically received. Officers elected by the Milwaukee group are as follows: Chairman, G. W. Smith; Vice-Chairman, C. W. Pendock; Secretary, W. S. Nathan; Treasurer, L. F. Reinhard.

SUMMER MEETING AT SPRING LAKE

New Jersey Coast Resort Selected for Gathering to Be Held June 24 to 27

Spring Lake, N. J., will be the site of the 1924 Summer Meeting. June 24 to 27 are the dates. This decision is announced by the Meetings Committee after a careful study of all available sites, the facilities and the accommodations of which are adequate for a gathering of the size and character of the Summer Meeting. In many ways, the requirements to be met by an S.A.E. Summer Meeting place are peculiar and Spring Lake seems to meet them more nearly than any other available resort.

First, there must be comfortable accommodations for 800 or more people and adequate dining rooms and service to feed them. The ideal location should be readily accessible by road as well as by rail. Climatic conditions must be given careful consideration. There must be satisfactory meeting rooms and places for outdoor exhibits and demonstrations. Recreational facilities are important; there must be golf courses, tennis courts, swimming pool, base-ball diamond and space for field events. The 1923 Summer Meeting demonstrated that all these specifications are met very satisfactorily at Spring Lake.

Three hotels will be used this year instead of two. This assures everyone the use of a room with bath and makes it

NATIONAL MEETINGS CALENDAR

TRACTOR MEETING
Chicago—April

SUMMER MEETING
Spring Lake, N. J.—June 24-27

AUTOMOTIVE TRANSPORTATION MEETING
New York City—Sept. 24-25

AERONAUTIC MEETING
Dayton—Oct. 3

PRODUCTION MEETING AND EXHIBITION
Detroit—Oct. 21-24

SERVICE ENGINEERING MEETING
Cleveland—Nov. 18-19

ANNUAL DINNER
New York City—January, 1925

MOTORBOAT MEETING
New York City—January, 1925

ANNUAL MEETING
Detroit—January, 1925

THE CARNIVAL
Detroit—January, 1925

unnecessary to assign members to the less desirable rooms. Meetings and headquarters will be in the Monmouth Hotel, and the Warren and the Essex and Sussex will supplement the accommodations of this establishment. Rates will be on about the same scale as that in effect last year. Further details will be announced in future issues of THE JOURNAL and *Meetings Bulletin.*

AIR-COOLED ENGINE RESEARCH

Franklin Engineer Discusses Back Pressure, Piston Temperatures and Starting

Excessive back-pressure in exhaust-manifolds and mufflers is a fault to be found in many modern motor cars. Resultant overheating of engines, valves and pistons may cause serious trouble which can be avoided with a little study, according to C. P. Grimes, research engineer of the H. H. Franklin Mfg. Co. Mr. Grimes gave an extremely interesting talk before the Indiana Section on Feb. 14, presenting in an informal way may practical developments and conclusions based on experiments in the Franklin laboratories.

Engine-testing procedure has been placed on a scientific plane in the Franklin experimental shops. Before starting a test, the engine is torn down and inspected thoroughly to see that the dimensions and the tolerances conform with the drawings. After reassembling, the engine is run for a few days to overcome initial tightness and any excessive friction. Combustion-chambers are each checked for cubical contents by measuring the amount of oil that can be held in each. The compression is checked with an O'Kill indicator. A neon-filled tube is so arranged in the ignition circuit that it projects a spot of light onto a polished brass disc which rotates on the crankshaft and thus the spark-timing can be checked accurately and visibly. Mr. Grimes emphasized strongly the value of the Leeds & Northrup potentiometer in engine testing, saying that he could not do satisfactory work without it. As an indication of the extreme care taken to secure accurate results, Mr. Grimes cited that friction tests of the engine are taken frequently throughout the period of any run to be sure that wear or improper lubrication has not introduced an error that might lead to wrong conclusions.

AIR-COOLED ENGINE TEMPERATURES

In the development and refinement of air-cooled engines, the Franklin organization has made many measurements of air and engine temperatures. The temperatures prevailing in the present design of engine are shown diagrammatically in Fig. 1. Mr. Grimes called attention to the fact that there is a considerable rise in temperature of the air between the points where it enters the cylinder fins and where it leaves them. This temperature rise is from two to three times that effected when air passes through the average radiator

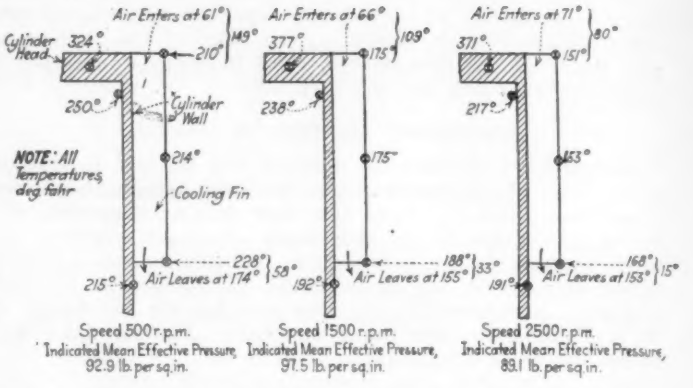


FIG. 1—CYLINDER AND FIN TEMPERATURES IN AN AIR-COOLED AUTOMOBILE ENGINE

All of These Measurements, Which Are in Degrees Fahrenheit, Were Made at Wide-Open Throttle with No Auxiliary Cooling at Speeds Ranging from 500 to 2500 R.P.M. In Obtaining These Temperature Readings Thermocouples Were Located at the Six Points Indicated and Were Connected to a Potentiometer That Read the Electromotive Force Produced by the Heat of Combustion. In Every Case the Very Hottest Point Was between the Spark-Plug and the Exhaust-Valve

of a water-cooled car. This better performance is due to the use of an efficient exhaust-fan and housing as opposed to the customary blade fan blanketed behind a radiator and in front of the cylinder block. Scientific design has reduced the power consumption of the cooling fan to 0.32 hp. at 10 m.p.h. and 1.30 hp. at 30 m.p.h.

Efforts to reduce engine temperatures to a minimum led the Franklin engineers to investigate the effect of exhaust back-pressure. It was found that the dual type of exhaust-manifold was of material advantage in reducing back-pressure, but even more effective means were developed. Each drop in back-pressure effected an increase in torque and power. Engine temperatures were reduced materially. Mr. Grimes said that some cars are produced today with manifolds that cause a back-pressure of from 8 to 14 in. of mercury. The present Franklin design reduces back-pressure to 2 in. of mercury, and maximum combustion temperatures have dropped from 520 to 260 deg. fahr. Stoves for heating intake air must be increased in size with each reduction in back-pressure since the exhaust is running cooler.

ALUMINUM PISTONS RUN MUCH COOLER

Comparative studies of piston-head temperatures with various types of piston and rings were made under Mr. Grimes' direction. The results of these are shown in the curves of Fig. 2. Note that the cast-iron piston runs 150 deg. hotter than the aluminum type. It is also interesting to note that pistons fitted with smooth-faced rings run cooler than those using rough-faced rings. Mr. Grimes attributed this to the greater friction of the latter type.

Air entering the carbureter should be heated, in Mr. Grimes' opinion, as this effects increased fuel economy if not carried to extremes. He recommended a temperature of 150 deg. fahr. Changes in the temperature of the intake-air affect the required degree of spark-advance. He also differed with authorities who claim that good distribution is attainable with wet mixtures. Efforts to get a high degree of atomization by using small-section high-velocity manifolds result in increasing the pumping losses of the engine.

STARTING MOTORS UNSUITED TO THEIR WORK

Easy starting in cold weather demands two engineering changes, in Mr. Grimes' opinion. First, starting motors must be made more efficient. The conventional small-diameter starter used today is most efficient at speeds of from 500 to 800 r.p.m., but it should produce its greatest torque at from 30 to 40 r.p.m., the condition met when cranking a stiff engine on a very cold morning. Mr. Grimes' second contention was that some form of electric primer should be used, such as that fitted to Franklin carbureters.

C. P. GRIMES

A. A. POTTER

This primer generates a combustible gas resembling cigarette smoke which remains in a fog state for ¾ hr. It uses only 221 watts to generate the gas and force it into the manifold. On the other hand, it is not unusual at zero temperatures to have a starting motor consume 1500 watts when turning a cold engine at 20 r.p.m. The electric device will be more positive and effective than any volatilizing device that depends upon suction, since this suction is equivalent to only 1½ in. of mercury when the engine is being cranked at 100 r.p.m.

Points Raised in the Discussion

During the discussion period Mr. Grimes answered many miscellaneous questions. He has not experimented with internally cooled exhaust-valves since the silchrome valves now being used give no trouble. He is favorable to the use of air filters to reduce oil contamination and excessive wear. The volume of air entering the carbureter is measured by a simple venturi in all Franklin-engine tests. Mr. Grimes explained the principle of the venturi tube and commended it to other research workers. He said that there was practically no difference between the temperatures of the front and rear cylinders in the Franklin engine. The distributing shroud is designed to direct 15 per cent more air to the rear cylinders than to the front. He said that he did not consider the compression-ratio such an important factor in fuel economy when it is considered that the average car is operated at part throttle most of the time and that the mean effective pressure is as low as 25 lb. per sq. in. at low loads and speeds. The closed-throttle condition increases the frictional loss of the engine due to the work of pumping against a high vacuum, and this friction horsepower is often greater than that required to drive the car.

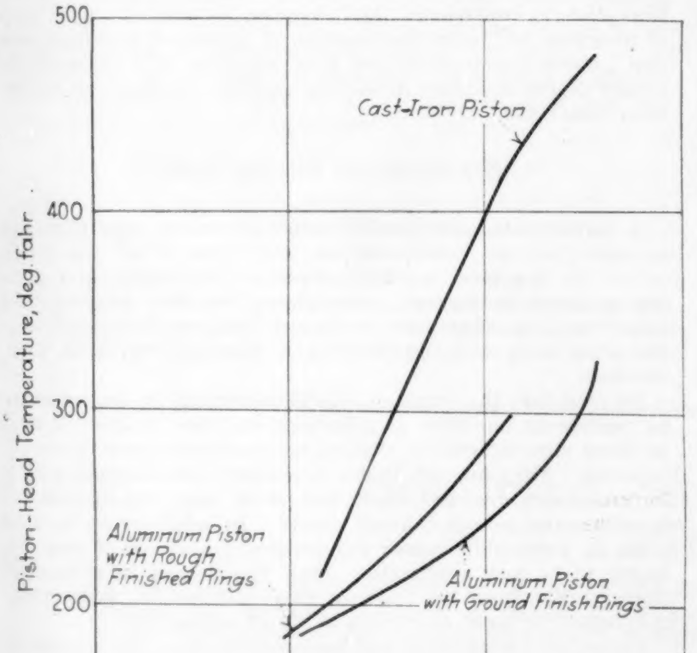


Fig. 2—Comparative Piston-Head Temperatures Using Various Combinations of Rings and Pistons

It Will Be Noticed That the Aluminum Piston with Rings Finished by Grinding Had the Lowest Piston-Head Temperature, While the Use of Rough Finished Rings Increased the Piston-Head Temperature Slightly Although the Cylinder Temperature Was Somewhat Lower. This Is Attributed to the Greater Friction of the Rough Rings. The Temperature of the Cast-Iron Piston with Pressure-Proof Rings Was Considerably Higher for Approximately the Same Cylinder Temperature

Lack of a proper chamfer on the entering thread of the spark-plugs caused preignition in one of the Franklin experimental engines. It was found that a tiny fin at the start of the first thread projected into the combustion-chamber soon heated to a red heat and preignited the charge.

Colleges Should Train Students to Think

Preceding Mr. Grimes' paper, Dean Potter of Purdue University gave an extremely interesting talk on Engineering Education and Trends. He said that the United States is now the Mecca for all people seeking education, and remarked that all should be given an opportunity to enjoy the benefits of education and not merely those who might be chosen as best fitted. The education of engineers is of great concern to the general public, since engineers will control largely the trend of future business activity. Teachers in schools and colleges must assist by building character into their students as a part of their educational function. They must train students to think and to use their minds, not merely stuff them with information. Dean Potter expressed this point humorously but effectively by saying that the technical school is not a brain restaurant but a brain gymnasium. He made a plea to industry generally to endow research fellowships at the technical schools of the Country and told how effective such a plan had been at Purdue University in making valuable engineering and scientific findings available for industrial enterprise.

Manifolds Indiana March Subject

Research studies of intake-manifolds will be presented and discussed at the meeting of the Indiana Section on March 6 at the Severin Hotel. H. W. Asire will read a comprehensive paper setting forth experience gained by the General Motors Research Corporation's staff from an extensive stůdy of manifold characteristics. O. C. Berry and others will supplement this with their data and conclusions. Indiana Section meetings start at 8 o'clock and are preceded by an informal dinner at 6:30 p. m.

HYDRAULIC SHOCK-ABSORPTION

New England Section Considers Important Factors of Riding-Comfort Problem

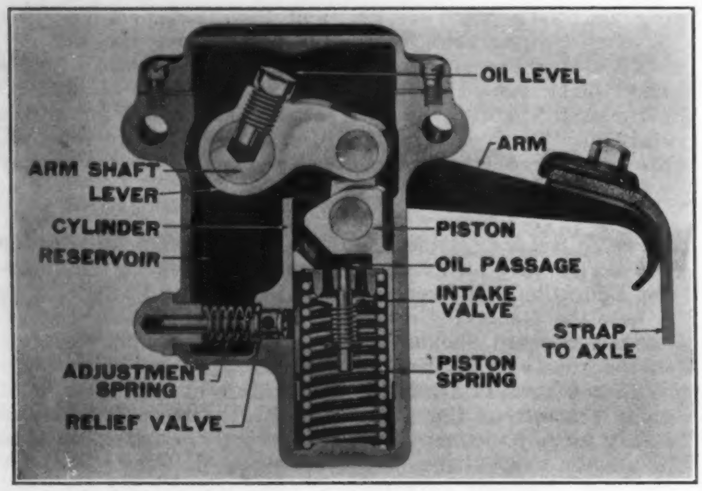
When and how should shock-absorbers function? Answers to this question were presented by E. A. Adams, of the Lovejoy Mfg. Co., Boston, before the New England Section at Springfield, Mass., Feb. 12, 1924, in a paper entitled Hydraulic Shock-Absorbers, Their Design, Construction and Application.

For ideal performance the springing of an automobile should be very flexible in compressive action and much stiffer against recoil. The practical ideal lies somewhere between the condition of flexible spring-action with perfect compression characteristics and normal recoil, and the condition presented by the same spring-action with no recoil. Normal recoil is excessive, while the condition of no recoil is applicable to the perfect absorption of one shock only; hence, the necessity for a compromise in shock-absorber design.

The hydraulic shock-absorber described by Mr. Adams is of the one-way, constant-resistance type; it functions against the spring action on the recoil only and exerts its restraining force equally at all periods of its working stroke.

The latter feature, constant resistance, was said to be preferable to the proportional resistance characteristic of certain friction absorbers, in that it makes possible a quicker recovery after each shock and therefore offers greater potential power to absorb the shocks immediately succeeding. The one-way action is accomplished by a fabric-strap connection between the axle and the absorber lever.

The construction and the method of operation of the



A One-Way Constant-Resistance Hydraulic Shock-Absorber

This Shock-Absorber Functions against the Spring Action on the Recoil Only and Exerts Its Restraining Force Equally at All Periods of Its Working Stroke. The Constant-Resistance Feature Is Said To Make Possible a Quicker Recovery after Each Shock and Thus Offers a Greater Potential Power To Absorb the Shocks Immediately Succeeding. The Fabric-Strap Connection between the Axle and the Absorber Lever Shown at the Right Accomplishes the One-Way Action. In Addition to the Simplex or Single-Purpose Model Illustrated, a Duplex or Double-Purpose Type of Similar Construction, but Having an Additional Relief Valve with a Stiffer Spring Is Also Made

hydraulic absorber described by Mr. Adams are made clear by the illustration, which shows the simplex or single-purpose model. The duplex or double-purpose type is similar in construction but is equipped with an additional relief valve with a stiffer spring. The second valve is thus allowed to function only when the shocks become too severe for the lighter valve. Under these conditions the piston-travel is sufficiently great to close the port of the lighter valve, but the heavier one still remains connected to the cylinder and opens at the desired pressure.

In conclusion, Mr. Adams brought out some of the difficulties encountered in applying shock-absorbers to various cars. He strongly advocated greater cooperation between automobile builders and shock-absorber manufacturers with a view to a standardization of the design of the parts and the fittings. It was believed that much unnecessary expense could be avoided in this way by making the application more easily accomplished.

The discussion of Mr. Adams' paper covered a number of interesting points that emphasized the importance in connection with the general riding-comfort problem of shock-absorbing devices and properly designed springs.

Before calling for adjournment, Chairman Northway announced that the next meeting of the Section would be held in Boston on March 11. Automobile Headlights, a subject of vital importance and widespread interest, will be discussed by R. E. Carlson, specialist in road illumination, Bureau of Standards, City of Washington.

QUALITY-QUANTITY PRODUCTION OF DATA

Mid-West Section Comes Across with a Heavy-Weight Symposium

Dominant features of the 1924 Automobile Shows; three standardized sizes of truck, tractor, harvester and "farmall" powerplant suited for universal usage; late detail developments of fuel utilization, manifold design and carburetion; outstanding tendencies in axle design and transmission history and development were the weighty subjects treated by the eminent speakers at the Mid-West Section Meeting held in Chicago on Feb. 8. In both quality and quantity, the data presented and the comments thereon were so well worth while that the meeting will be long remembered by those who attended it.

Features of the Shows

H. L. Horning gave a racy account of his impressions while circulating through and throughout the big show places that housed the 1923 products of the automotive industry, of which it is so justly proud and upon which it staked its reputation and its future hopes.

Balloon tires and their advantage in providing increased riding comfort and longer life for the vehicle were first mentioned by Mr. Horning, and he commented upon the six-cylinder engine's advantages regarding better balance and consequent decreased vibration when compared with the four-cylinder engine, voicing also his approval of the Maxwell-engine front-support recently developed as a vibration reducer.

He remarked favorably on the Cadillac crankshaft, the Chandler gear shift designed to simplify gear shifting, the Chrysler oil-filter and the general trend toward the securing of a continuous supply of fresh oil on bearings to prevent wear and provide more nearly perfect lubrication. Referring to four-wheel brakes, he called attention to the danger of too great confidence in their stopping ability that may lead many drivers to delay brake application until after they pass the boundary of a danger zone, rather than to apply the brakes sooner and thus err on the side of safety.

Improved engine balance, resulting from the use of balancing machines, is considered by Mr. Horning a real achievement. Other features that markedly indicate progress are the improved steering-gears and shock-absorbers, rubber-cushioned springs, self-lubricated bearings, plain-bearing fans and transmissions. Mr. Horning believes the next step of progress will be in the direction of improved transmissions and proper gear-ratios, and that attempts will be made to obtain better economy inside the combustion-chamber rather than inside the carbureter.

Standardized Engine Sizes

A standardized and graded series of engine sizes that are suitable for the volume-output requirements of the fields served by tractors, trucks, harvesters, threshers and general-purpose, or farmall, powerplants, so that such engines also would be adaptable in design features and applicable for other uses, was illustrated and described by O. B. Zimmerman.

He said that the result of this development by the company he represents has been satisfactory and that it has resulted in three sizes of engine that range, approximately, from 20 to 45 hp. They operate under conditions that demand power for transport, drawbar work, belt work, and combinations of drawbar and power take-off needs. In addition to normal truck or automobile power requirements, a series of requirements to be met exists that affect the design to a marked degree; therefore, the engines have distinctive characteristics suited to their respective fields of operation.

Reliability, durability and accessibility are the outstanding features. The three sizes are 3¾ x 5 in. to operate between 850 and 1800 r.p.m., 4¼ x 5 in. to operate between 1000 and 1600 r.p.m. and 4½ x 6 in. to operate at 1000 r.p.m. Complete enclosure against dust and dirt is provided. The engines are four-cylinder, four-cycle, vertical type, have removable cylinder sleeves, a two-bearing ball-bearing crankshaft and overhead valves. The design is sturdy and is arranged so that three- or four-point support can be utilized at the option of the designer.

The ignition system on these engines is universal and generally uses a high-tension magneto, but it can be arranged easily for battery and timer head or dual ignition. The angle of ignition slightly exceeds 40 deg. For the heavy units, the fuel system is designed primarily for operation with kerosene, but it is adaptable to gasoline usage. Fuel consumption is approximately the same for kerosene and for

THE MEN WHO TOOK A PROMINENT PART IN THE FEBRUARY MEETING OF THE MID-WEST SECTION
From Left to Right They Are G. W. Smith, F. C. Mock, H. L. Horning, O. B. Zimmerman and W. F. Rockwell

gasoline in amount, but the better economy pertains with kerosene. Splash lubrication with forced circulation is used. Cooling is effected by a thermosiphon system that has a radiator of generous size and an auxiliary fan.

Governing is a prime essential and is effected by throttle control. For field operations, satisfactory air-cleaning and muffling against fire and noise are provided for. From flange to flange, these units constitute a standardized manufacturing plan which, with the attachment of the magneto, the timer, the generator and the starter, includes a series of 48 possible combinations without interfering with multiple manufacture, since 90 to 95 per cent of the engine is included between the flanged ends. Hence, the engine can be adapted to varied uses. Eleven units are being manufactured at present: Trucks, 7 sizes; tractors, 2 sizes; harvester threshers, 1 size; and farmall, 1 size.

FUEL, CARBURETER AND MANIFOLD

Progress in the detail developments of fuel utilization, carburetion and manifold design was outlined and illustrated by F. C. Mock. Aided by lantern slides, he described the efforts that have been made to improve conditions.

Regarding fuel utilization, collector jars between the carbureter and the manifold were used and manifold forms were observed in studying mixture conditions. Fuel exists in the mixture in three forms: Vapor, believed also to be mixed with air; fuel mist, a gray silvery fog apparently composed of fuel drops surrounded with a saturated vapor atmosphere, and that is distributed somewhat uniformly; and the liquid gasoline itself, in the form of the heavy elements that are deposited on the cylinder walls. The belief is that the liquid gasoline is responsible for the difficulties that are experienced.

Shapes of manifold were shown designed to give a streamline flow around bends that is a continuous and a non-eddying flow for the mixture. The average manifold was stated to deliver, to at least one of the cylinders, four times as much mixture as to some other cylinder, with a corresponding excess amount of liquid fuel intermingled and deposited.

The skill of the engineer should be directed toward using the minimum amount of heat that will accomplish vaporization. Another essential is to obtain that heat as soon as possible after starting. The heating effect of a hot-spot is not so simple as may be thought. Some heat is absorbed by the mixture and some by the walls, and the engine does not attain a normal operating condition until all the walls have reached their temperature equilibrium. Also the effect of a hot-spot is determined by the amount of surface exposed to the exhaust as well as that exposed to the intake. Good results seem to be obtained by an arrangement by which the

Schedule of Sections Meetings

MARCH

5—MINNEAPOLIS SECTION—Analysis of Design and Adaptability of the Low-Pressure Tire—L. O. Grange
6—INDIANA SECTION—Research on Intake-Manifolds—H. W. Asire; O. C. Berry
DETROIT SECTION—No specified subject—C. F. Kettering
7—WASHINGTON SECTION—Four-Wheel Brakes—W. S. James
11—PENNSYLVANIA SECTION—Balloon Tires and Riding Quality—James E. Hale
NEW ENGLAND SECTION—Road Illumination—R. E. Carlson
13—METROPOLITAN SECTION—Highways for Motor Traffic—Walter L. Kidde and William G. Sloan
14—MID-WEST SECTION AND MILWAUKEE GROUP—Joint meeting in Milwaukee—Four-Wheel Brakes—A. Y. Dodge
17—CLEVELAND SECTION—Traffic Control—Major Mark Ireland
20—DETROIT SECTION—Recent Developments in Permanent-Mold Castings—Dan H. Meloche

APRIL

3—DETROIT SECTION—Chassis Lubrication—Fred H. Gleason
15—NEW ENGLAND SECTION—Chassis Lubrication—Fred H. Gleason
PENNSYLVANIA SECTION—Four-Wheel Brake Meeting

surface exposed to the intake is smaller and made integral with the exhaust. Mr. Mock believes that the location of a hot-spot opposite the carbureter opening is good practice, but also that there must be some heat where the fuel drains. The ideal condition appears to be represented by a small heating surface integral neither with the exhaust nor the intake.

In Mr. Mock's opinion, it will be appreciated within another year that it is unnecessary to drive a car miles to get it warm. He thinks a satisfactory hot-spot application is simply a breaking-up of the liquid flow; when the liquid fuel strikes the hot-spot it pops off, so becoming more easily air borne. The chief difficulty in using kerosene as fuel is to handle it immediately after it leaves the carbureter; if it can be made to impinge upon the hot-spots before it settles on the walls, there is a better chance of making an engine run well on kerosene.

Tendencies in Axle Design

Some outstanding tendencies mentioned by Williard F. Rockwell when presenting his paper on the above subject are chronicled here, the entire trend as Mr. Rockwell visualizes it being in too great detail for publication at this time.

Tendencies of the industry toward lower costs has been reflected in axle design. Large-volume business has made it worthwhile to introduce changes in the design of passenger-car and light-truck axles to increase production economy and improve design. For heavy trucks, the trend has been to keep costs down by making no changes that would involve added expense for tools, jigs, dies and fixtures. Front-wheel brakes for passenger cars have resulted in changing front-axle I-beam sections and front-spring design to take care of the increased stresses such brakes introduce.

In the design of rear axle for passenger cars, no fundamental change has occurred, although the change from the full-floating and three-quarter floating types to the semi-floating axle and a change in mounting the bevel pinion are two features that seem to be coming to the fore. As to the latter, the overhanging pinion formerly predominated; but many manufacturers have changed and some will change this year to a straddle mounting.

Mr. Rockwell expects the introduction of worm-drive passenger-car axles within the coming year. With regard to motor-truck rear-axle types over a period of several years, the bevel-gear axle has steadily increased in favor due to low cost and efficiency for light trucks. A 5-ton truck recently brought from Europe has a bevel-gear axle and is equipped with solid tires. A straight-tooth bevel is used with a 7-tooth pinion and a 56-tooth ring-gear; this gives only an 8 to 1 reduction, whereas most 5-ton trucks in this Country require at least a 10 to 1 reduction.

For 6 years, the worm-drive truck-axle has been more popular than all other types; for any given reduction, it is possible to obtain a suitable gear-center, a favorable lead-angle and a low tooth-pressure, which will give high efficiency at normal operating speed. The worm-drive has a mechanical efficiency none too high, but it has justified its existence. The declining popularity of the internal-gear drive may be due to its increased price; the chain drive probably will remain in the field, as some prefer it to all other types.

All axle manufacturers are trying to reduce unsprung weight. The double-reduction axle unquestionably has shown the greatest increase in popularity under heavy-duty vehicles. In the spur and bevel type, it is possible to select spur and bevel pinions that have a sufficiently large number of teeth for high efficiency, together with a heavy pitch and satisfactory cross-sections for the ring-gears to hold distortion within reasonable limits by heat-treatment. Its efficiency is high throughout the working range, and changes in ratios can be made quickly without serious effect on the various components. This type of axle was chosen by leading English experts for the heavy-duty British subsidy war trucks.

Future axle-design will be influenced by balloon tires, with a consequent reduction of the brake-drum diameters; by greater reductions and more steps in transmissions; by desires for greater road clearance and body clearance, and more satisfactory brakes and possibly by the use of three or more axles, two or more being driving axles, to obtain greater safety, better load-distribution and better traction with less damage to roadbeds. Balloon tires may force the use of axles that provide a wider car-tread.

To date, transmissions have been designed to operate approximately 5 per cent of the time a truck is in service; additional requirements in this respect will necessitate changes in design. The interest in transmissions leads Mr. Rockwell to believe that the two-speed rear-axle will be demanded very soon. He showed pictures of a new design of motorbus axle and an axle for railroad use that is arranged for four-wheel drive, provides gear positions for idling and reverse driving and permits the use of all transmisson speeds in either direction of travel.

Transmission History and Development

In presenting this subject, George W. Smith said in part that, from an idealistic viewpoint, the transmission unit of a motor vehicle possibly is the least satisfactory of any in the entire mechanism, although present transmissions are mainly satisfactory in the ordinary operator's opinion. Gradual and continuous improvement as to simplicity and durability has taken place in the last 10 years, but very little change in the form or method of operation.

Transmissions exist to convert low torque to higher torque, and this requires a corresponding reduction in the speed. This result must be accomplished with the least possible loss of energy. Friction devices and planetary or epicyclic gearing appear to have been the favorites during the early development; however, these designs afforded but two speeds forward and a reverse, which was not sufficient to handle the heavier vehicles. Present practice, on cars weighing more than 1700 lb. and selling for more than $500, is almost universal in using spur gearing of the so-called selective type.

During the transition period from planetary transmissions, a form of gearing known as the progressive type was used; it required the full sequence of engagements to be made between each speed, an unduly long and inconvenient movement of the arm, and a lack of ability to maneuver. The present form of transmission is fairly compact; its most noteworthy characteristics being simplicity, ruggedness, efficiency, reasonable cost, durability and accessibility.

It is Mr. Smith's belief that most of what little demand exists for change in transmissions comes through sales departments and from a desire to attract the attention of a limited number of people who protest against operating a change gear. On the other hand, he said it cannot be denied that it is far from perfection to cut power transmission entirely loose by releasing the clutch while shifting a gear into engagement. Although a better mechanism is desirable, such a goal seems far distant.

Electric and also hydraulic transmissions have been tried with but slight success. Various mechanical forms have been developed, the general characteristic being that the gears operate in pairs fixed axially, one being keyed to a shaft, the mating gear being free to revolve on a plain or anti-friction bearing.

Regarding the future Mr. Smith quoted some authorities to the effect that the planetary form has a good chance to "come back." The Lanchester Company has developed this form to a high degree in England, but indications are that it will be costly. He described other systems of transmission and discussed gear-shifting devices, saying of the latter that they are attracting considerable attention and will be used if the public so demands.

Many other interesting and very instructive points were brought out by the illustrations presented during the delivery of the foregoing papers, and the same can be said of the points covered by the members present who participated in the several discussions. It is expected that these points will be published later, after the authors and discussers have been given an opportunity for verification.

VIBRATION IN FOUR-CYLINDER ENGINES

Unbalanced Inertia Forces of the Reciprocating Parts Given Consideration

L. C. FREEMAN

Engine suspension as a factor of great importance in the reduction of objectional vibration was treated at length on Feb. 7, 1924, at the Detroit Section Meeting by L. C. Freeman, executive engineer for the Maxwell Motor Corporation, Detroit, who presented valuable data relative to engine balance. In substance, Mr. Freeman said that vibration in four-cylinder engines is due principally to the unbalanced inertia forces of the reciprocating parts and that his statements are confined solely to such forces. Two factors govern, at any speed; (*a*) connecting-rod to crank ratio and (*b*) the weights of the reciprocating parts. He believes that full advantage has been taken of present possibilities of weight reduction in recent aluminum-alloy piston and connecting-rod developments. It seems probable that lessened vibration, rather than increased thermal conductivity or lowered bearing pressures, has been the controlling factor in the increasing use of aluminum-alloy pistons in four-cylinder engines.

Increase in connecting-rod to crank ratio means an increase in the weight and the cost; so, present-day practice probably results in economic if not in mechanical balance. Where it is not possible to eliminate the cause of objectionable effects, often they can be offset or neutralized by other means. So far as the passengers are concerned, the effects of four-cylinder-engine vibration can be eliminated as completely as though the cause were removed, in one instance by a construction such that energy is absorbed at a rate that makes resonance impossible. In the analysis presented, Mr. Freeman did not claim it to be complete or mathematically exact, but believes the method provides sufficient exactness so that practical application can be made.

VIBRATION-REDUCTION METHOD DESCRIBED

In principle, Mr. Freeman advocates locating the rear supports so that the center of percussion of the unit falls in the plane of the resultant of the unbalanced inertia forces, and then providing a vibration or energy-absorbing element at another point so as to prevent resonance in the frame structure as its natural frequencies of vibration are approached or passed through.

Regarding the resultant of the unbalanced inertia forces, it acts in a plane midway between cylinders Nos. 2 and 3. The moment of this resultant force about a transverse axis through the center of oscillation tends to rotate the engine about that axis; it results in an approximately vertical movement at the front supports and in no tendency for the center of oscillation to move relative to the car frame. Therefore, the rear engine-supports should be located at such a point and, inasmuch as the centers of suspension and oscillation are interchangeable, the center of percussion is thereby brought into the plane of the resultant of the unbalanced inertia forces.

Mr. Freeman believes this to be strictly true when the engine is supported only at the original axis of oscillation, and that it is wholly independent of the frequency or magnitude of the forces acting so long as the movement is small. If the unit is rotated about the axis into an approximately horizontal position and maintained there by a flexible support located in the plane of the resultant inertia force, there still is no reaction at the rear supports. In other words, one point on the engine has been found at which it can be attached to the frame without the transmission of any vibration at that point.

DETERMINATION OF THE CENTER OF OSCILLATION

(1) Find the center of gravity of the powerplant unit

(2) Suspend the engine from the axis formed by the intersection of a plane intersecting at right angles the plane of the cylinder axes midway between the axes of cylinders Nos. 2 and 3 with a plane containing the center of gravity, these planes being at right angles to the plane containing the cylinder axes and to each other

(3) Observe the time t, in seconds, of a single oscillation of the engine so suspended, and compute the length L of the equivalent simple pendulum by the formula $L = 12\, g\, t^2/\pi^2$, in which g, the acceleration of gravity is 32.2 ft. per sec. per sec.

(4) Locate the center of percussion by measuring the distance L in inches in the direction of the center of gravity from the point determined by the intersection of the three planes. A line in the plane of the center of gravity as defined in item (2), parallel to the axis of suspension and passing through the center of percussion will be the desired axis of the engine support which should, theoretically, be in the form of a trunnion. With the engine suspended from this new axis, the original axis of suspension then becomes the center of percussion and is in the plane of the unbalanced inertia forces of the reciprocating parts

RESULTANT INERTIA-FORCE CHARACTERISTICS

Stating that the inertia forces of the reciprocating parts can be represented by the summation of an infinite series of cosine curves progressively increasing in frequency and decreasing in amplitude, Mr. Freeman said further that the first overtone is the most important and has a frequency of vibration of 2 per revolution. These forces act all the time the engine is in motion but are in evidence only at certain speeds, usually not the highest speeds at which the forces are the greatest, as they vary as the square of the speed. The reason is that the amplitude of the resultant vibrations of the frame is very small, except where its natural frequencies are approached or passed through. If an energy-absorbing element is introduced between the engine and the frame, the amplitude of the frame vibration can be kept so low as to be unnoticed even at the resonant frequencies.

Illustrating this last statement by mentioning a child's swing, that is kept in motion by the application of intermittent impulses in time with the natural frequency of the swing, Mr. Freeman said that if the frictional loss at the pivots plus the wind resistance plus the friction caused by the dragging of the child's feet on the ground, per oscillation, is not equal to or greater than the energy input per oscillation, the amplitude will increase; if it is greater, the amplitude will decrease. He said also that this is exactly what has been accomplished by making the front support in the form of a thin leaf semi-elliptic spring having sufficient interleaf friction to counteract the energy input per oscillation at the synchronous frequency. It is believed also that the location of the rear support is important; the method of attachment to the frane can be modified. As the work to be done varies only directly as the weight of the piston, Mr. Freeman believes further that, even if future piston developments necessitate a slight increase in weight, vibration still can be controlled by providing the necessary amount of friction in the front supports.

POINTS BROUGHT OUT IN THE DISCUSSION

Asked how the plane of the crankshaft is kept horizontal when balancing, if the engine is not suspended at the center

of gravity, Mr. Freeman said that no particular attempt is made to keep the plane of the crankshaft horizontal but that the important feature is where the rear engine-support is located; the center of gravity and the axis are in the same plane but that is not necessarily a horizontal plane. Also, that the engine was swung from an axis between cylinders Nos. 2 and 3, as a pendulum, merely for the purpose of determining the correct position for the final location of the rear support, the center of gravity coming directly below it. Further, that he has observed no great influence, so far as transmission of engine vibration to the frame is concerned, as a result of the action of the universal-joint having its center line displaced from the axis of suspension of the engine.

Regarding the actual suspension of the engine, Mr. Freeman said that some brackets were cast, machined and attached to the engine so that the center line of the trunnions was on the axis formed by the intersection of the two planes he described.

A. A. Bull said that the crankshaft of six-cylinder engines generally show greater deflection due to whipping and that, particularly on such engines, he believes the greatest benefit comes from a reduction of crank-throw; that is, it seems fairly well established that troubles due to vibration are minimized greatly by a reduction in the length of engine stroke.

SMOOTH-RUNNING ENGINES

Distribution, Turbulence, Compression and Other Factors Affect Balancing

J. Edward Schipper

Although heavy camshafts, light and accurately made reciprocating parts and rigid supporting structures were acknowledged by J. Edward Schipper, field editor at Detroit for the Class Journal Co., as playing an important part in making the modern high-speed passenger-car engine run smoothly, he called attention also to other considerations that many designers overlook when laying out a power-plant that is to be free from "rough spots" and "periods," in presenting a paper on Engine Balance at the meeting of the Detroit Section held on Feb. 7, 1924.

Among these other considerations, distribution of the fuel mixture to the engine cylinders as it affects engine smoothness has been recognized only recently in regard to its true importance as a disturbing element. Higher compression pressures and the utilization of turbulence to speed-up the rate of flame propagation have resulted in increasing the explosion pressures to such an extent that variations in the maximum pressures of different cylinders have become much more marked and exert a much greater influence on smoothness of operation. Recent studies of distribution made by analyzing the exhaust gas from individual cylinders have shown that the mixture percentages vary to a startling degree in different cylinders of engines thought to be fairly efficient; hence, explosion pressures vary tremendously and defeat effective engine balance.

What Must Be Done To Supplement Balancing

Before the usual balancing methods can become effective, every precaution from the standpoints of distribution, compression, timing, sealing and turbulence should be taken to produce uniform combustion conditions; the maximum and the mean-effective pressures should be the same, the volumetric efficiencies of each cylinder should be equal and so should the thermal efficiencies of each cylinder. Even though this ideal cannot be realized under practical production conditions, it can be approached so nearly that the variations are minute.

Forces dealt with in practical engine-balancing are known, but they vary with the number of cylinders and their arrangement. Vibration occurs in a four-cylinder engine because of the displacement of the engine's center of gravity caused by the angularity of the connecting-rod. A condition of inherent balance practically ideal is presented by the six-cylinder engine because the reciprocating forces are in balance, but torsional vibration increases as the crankshaft becomes longer and a heavy crankshaft must be used to eliminate the torsional vibrations within the running speeds of the engine. However, the mere employment of a heavy crankshaft will not put a six-cylinder engine into perfect balance.

Many practical considerations enter the process of balancing a crankshaft. It is necessary to put the crankshaft into static and into dynamic balance before assembly. As to the crankshaft and flywheel assembly, the crankshaft can be in perfect balance and the flywheel likewise but, if they are assembled with an eccentricity of say 0.001 in. due to faulty mounting, the time and labor expended in securing balance of the two individual units will have been thrown away. Concerning flywheel balance, it is essential to balance the clutch as an assembly and also to pay at least some attention to the universal-joints and the propeller-shaft.

Mr. Schipper said further that the designer will keep his engine as short as is consistent with the cylinder-bore, the amount of water-cooling space between the cylinders and the number of bearings used for the crankshaft. He mentioned the flywheel effect of the front-end drive, the fan-pulley, fan and the like as factors meriting consideration, and suggested future discussion from those who advocate the use of two flywheels. Reduction of reciprocating weight is desirable; counter-weighted shafts are increasing in number; methods are being evolved in the forge shop for producing complete integral counterweights from a production standpoint.

Regarding synchronized vibration, Mr. Schipper said that although vibration and noises at the front end of an engine have been thought to originate at the front end and probably do to some extent, he believes that in many instances vibrations in other parts of the engine are transmitted to the front end so that the front end, particularly a front-end chain, will act as a detector of these vibrations.

The Discussion

In reply to questions, Mr. Schipper said that when the crankshaft is balanced with the flywheel, it is the practice to balance crank, crankshaft, cheeks and all else as one assembly. The balancing machines indicate what amount of metal is to be removed and where it must be taken off to put the shaft in balance; this is true whether parts are balanced separately or as an assembly.

W. R. Griswold discussed vibration and balancing with reference to the eight-cylinder engine. Among other things he brought out that an engine may have a certain critical speed on the dynamometer but, when put into a car and coupled with the propeller-shaft, the universal-joint, the rear axle and the tires the result may be entirely different; the general effect is that the critical speed will be lower. He gave an instance of an engine smooth within the driving range in one car, but very unsatisfactory after having been transferred to another car with a higher gear-ratio and larger tires; this illustrates the fact that all parts of the car, including the tires, influence vibration and that other considerations beside those for engine characteristics must be included. Asked to compare the vibration due to the reciprocating masses in six-cylinder-in-line and eight-cylinder-in-line engines, Mr. Griswold said that, at 3000 r.p.m., the unbalanced forces amount to about 28 lb. for a six-cylinder-in-line and 32 lb. for an eight-cylinder-in-line engine such as are built by the company he represents.

With regard to the use of two flywheels to reduce vibra-

tion and a statement of an instance in which two flywheels had caused torsional vibration, Mr. Schipper said that he had talked with several persons and that there seems to be no way of predicting what the effect of the second flywheel will be. It varies in different cases. On certain engines, a second flywheel has caused a torsional periodic vibration that gave trouble; on other engines, its installation eliminated periodic vibration that had been giving trouble. One manufacturer expressed his intention to make provision on his engines for a second flywheel, so that one could be installed if that were later found desirable.

DO OPERATING COSTS INCREASE WITH AGE?

Factors That Tend to Raise the Costs of Fleet Operation and Maintenance

A well-attended meeting of the Metropolitan Section, held at the Automobile Club of America on Feb. 14, listened with interest to R. E. Plimpton, associate editor of *Bus Transportation*, discuss An Analysis of Costs for 10 Years of Fleet Operation. The paper was supplemented by numerous charts showing graphically the rise and fall during successive years of the several items entering into the cost of operation and maintenance.

R. E. PLIMPTON

Diverse opinions exist, said Mr. Plimpton, as to whether it is economy to salvage, or junk, old equipment and replace the vehicles with others of later and uptodate design, or whether, with proper attention, the costs depending on maintenance and operating efficiency can be kept fairly constant and present-day motor vehicles be run indefinitely with a profitable net result to the owner. Comparing the chassis of a motor truck with a locomotive, it is the general opinion of railroad officials, he said, that when proper running repairs are made locomotives will continue in service with their full original earning capacity, and that locomotives are not retired because they are worn out but because newer types are considered more economical for a particular class of work. In this case the old locomotives continue to be used in other kinds of service.

On the other hand, he said, it is maintained by some that the cases are not parallel inasmuch as present designs of truck cost more and more as they grow older, successive overhauls are more expensive, routine repairs cost more, breakages are more frequent, and the parts increase in price or cannot be bought at all and must be made to order.

During the last 10 years only minor changes in the construction of motor trucks have taken place, the weight, the fuel consumption, the price and the performance remaining practically constant; but, because of the adoption of a settled policy of inspection, adjustment and overhauls, many valuable lessons in maintenance have been learned.

Replacement or renewal of a complete vehicle may become necessary because of physical depreciation, obsolescence or inadequacy. The last named is particularly apt to affect common carriers, as the type of equipment demanded by the public must be provided, or a loss of revenue may result. The tendency in this matter, inasmuch as operators are limited to a just and reasonable return on the valuation of the property, seems to be to follow the principles laid down in railroad valuations. In a recent application for increase of fare by a motorbus company in Albany, the commission made a valuation of the property on the basis of the first cost of the motorbuses and the garage tools, from which was subtracted the depreciation reserve, and to which was added a working capital of $2,000, half of which was for cash capital and half for use in buying supplies. Eight per cent return was allowed on the total valuation but the fare was based on the number of passengers carried per month during certain winter months. Special attention was called by the commission to the duty of providing adequate lubrication and of making repairs at once when needed.

In opening the discussion, C. W. Sater said that there would be no depreciation if parts could be purchased at nominal cost. He asserted that since 1919 the cost of repairs had increased 50 per cent, the rate of depreciation had dropped 70 per cent, and the operating cost had been reduced 23 per cent.

In the opinion of W. H. Woods, the rise or fall of costs depends largely on the accounting system used. The character of the management is of the utmost importance. Depreciation and repairs should offset each other. Inspection and lubrication should have careful attention. The gun system of lubrication and the filtering of air, he said, both have the effect of lowering the depreciation of trucks.

John McLachlan stated that no records had been compiled showing just what life might be expected of a truck. Experience has shown that they run more efficiently after the first year so far as gasoline and oil consumption are concerned. The more attention that is given them and the more effective the lubrication, the longer they will last. Each make of motor truck has its own peculiarities.

As a truck gets older, Joseph McLaughlin believes, it gets older in every sense of the word; the number and cost of repairs gradually increase. He said the life of a truck is indicated by the number of its moving parts. A study should be given to a truck to determine the point beyond which it is uneconomical to operate it longer.

Robert Hebron opined that a truck could still be put into good condition and run economically even though it might have had 8 or 9 years of service.

A truck will never wear out if properly maintained. Buses, said V. E. Keenan, now run more in a single year than they formerly did in a lifetime. The question is one not only of maintenance but of knowing what not to buy. The railroads have been forced for many years to have a standardized system of accounting, which might be applied advantageously to truck operation. Fleet operators should give careful attention to the design of trucks and to the accessibility of parts. Too little attention is given to this subject by engineers, who should work in cooperation with operators with a view to making all parts accessible.

Ten or 12 years' experience in the maintenance business has shown him, said J. F. McMahon, that a cab built 4 or 5 years ago cannot be used today because of the comfort demanded by the passenger of today. He said that his company continually made changes in design to increase the accessibility of parts and to decrease the cost of making repairs. As a result the cost of repairs has been brought down until it is now about 1 cent per mile. Each part has its troubles carefully analyzed. When disc clutches were first brought out the instructions were to run them dry, but they were found to run better in oil. The first tendency of the fabric was to wear off and of the clutch to become gummed, but oil washes it. It also eliminates abrupt shocks. When the bearings and the camshafts began to give trouble it was found that the use of white-metal bearings gave three times as long a life as bronze bearings gave. When brakes became loose the inclination was to tighten them but this did not cause the cars to stop more quickly; whereas increasing the leverage was found to decrease the repairs 60 per cent. Life is not a question of years but of mileage. A truck averages 15,000 miles per year; a cab, 50,000 miles. A play in the spring-shackles of 1/64 in. is very annoying to the passenger. Rubber shock-absorbers have been adopted as standard. Cabs carry an average of 1⅞ passengers per mile and some cabs have covered more than 500,000 miles.

Replying to questions, Mr. McMahon said that no failures of front axles had occurred. Frames, subjected to greater

stress in some parts than in others, are reinforced. The first parts of the cab to give way were the bolts and bushings of the spring-shackles. Frames run from 80,000 to 100,000 miles before checks are noticeable, but they break only because of physical damage. Special study has been given to lubrication, and his company is now able to control oil-pumping.

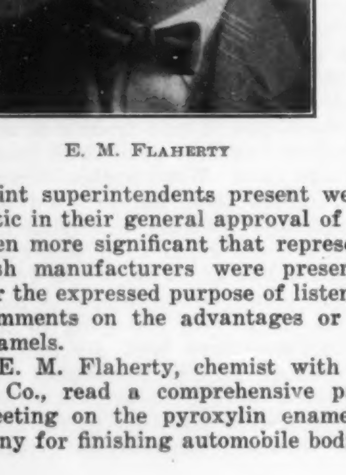
David Beecroft stressed the importance of reducing the cost of transportation. He said that 8000 companies operate from 3 to 5000 vehicles each. Some operate three vehicles each of a different make. This is due to the confusion created in the minds of operators by the arguments of salesmen. The need is for more designers who look at the vehicles from the viewpoint of those who use them. In his opinion, maintenance depends on the accuracy of the inspection system. Accessibility is the feature that must be drilled into the heads of designers. The personal element has not been sufficiently stressed; drivers have not been urged strongly enough to think of the improvements that can be made. Bonus systems have been introduced in some shops with this end in view. The time when a vehicle has to be withdrawn from service usually depends on the carefulness of the driver's inspection and the maintenance the vehicle receives.

Giving attention to the personal element and paying drivers of buses on the basis of their performance, in the opinion of Mr. Sater, had improved their efficiency 23 per cent. In 5 years the company had lost only 5 men out of 134.

One reason for improvement among the drivers of his company, as noted by C. O. Bech, is that the drivers have been trained to handle the equipment. Buying new trucks of a different design means that new parts must be kept in stock and that troubles increase. He said that the men in his company are primarily solicitors rather than drivers and that frequently the company finds it to be of advantage to keep a man who is a good salesman though he may be a poor driver.

PYROXYLIN ENAMELS FINDING FAVOR

Cleveland Section Speaker Tells How New Body Finish Is Made and Used



E. M. FLAHERTY

Pyroxylin enamels seem to be the automobile body finish of the future, except possibly in the low-priced car field where baked black enamel will undoubtedly survive. Last December in Detroit a paper on pyroxylin enamels was received with great interest, but the discussion reflected general skepticism toward these revolutionary materials and the extravagant claims made for them. At the Cleveland Section Meeting on Feb. 18, an entirely different attitude prevailed. The motor-car engineers and paint superintendents present were outspoken and enthusiastic in their general approval of pyroxylin enamels. It was even more significant that representatives of paint and varnish manufacturers were present in considerable number for the expressed purpose of listening, rather than to venture comments on the advantages or disadvantages of the new enamels.

E. M. Flaherty, chemist with E. I. duPont de Nemours & Co., read a comprehensive paper before the Cleveland meeting on the pyroxylin enamels developed by that company for finishing automobile bodies. Much of the substance of his paper was a repetition of the two papers read at the Detroit Section Meeting last December and readers are referred to p. 90 in the January issue of THE JOURNAL for a complete report of that meeting. Mr. Flaherty's paper described the ingredients and the chemical manufacturing processes more comprehensively than did the previous papers and this part of his paper is printed herewith as an important addition to the material previously published.

HOW PYROXYLIN ENAMELS ARE MADE

The basis of pyroxylin enamels is a type of nitrocellulose known as pyroxylin. Pyroxylin, chemically, is cellulose nitrate with a degree of nitration corresponding to a percentage of nitrogen between the approximate limits of 11.0 and 12.5. From 11.0 to 11.8 per cent the product is employed in the so-called celluloid plastic industries. When mixed with camphor or similar agents it is readily plasticized by heat and can be molded into almost any shape. It is not readily soluble, however, in liquid solvents. From this nitrogen content of 11.8 up to 12.5 per cent the solubility of the resultant product changes radically, and we have a grade that dissolves perfectly in such solvents as acetone, amyl acetate or methyl alcohol. This grade of nitrocellulose is the basis for the whole soluble pyroxylin industry and is the type from which body enamels are made. It is possible to nitrate cellulose to a still higher degree, giving an ultimate nitrogen-content of about 13.5 per cent, but the products in this range are not soluble in the usual solvents and are known as gun cottons. This degree of nitration is the essential difference between the soluble pyroxylins and the gun cottons of the explosive industries.

In the manufacture of pyroxylin the basic material is cotton. For economy it has been found possible to use cotton linters, that is, the shorter fibers remaining on the cotton seed after the longer fiber has been removed for spinning into thread. These linters are usually obtained from the cotton seed mills where they are removed from the cotton seed before crushing. Crude linters vary in color from a gray to a medium brown, due to the presence of oils, wax and small particles of hull fiber. Before nitration all of these impurities must be removed completely, and the purification of the linters is an elaborate process, starting with the digestion with chemicals under pressure in large steel autoclaves followed by bleaching treatments and a series of washings to remove all traces of chemicals used. The last step in the purification is a thorough drying in a machine resembling a paper mill. At this stage the cotton has been transformed from the gray or brown linter to a snow white product resembling absorbent cotton in appearance.

NITRATION PROCESS TRANSFORMS COTTON INTO PYROXYLIN

The next step is nitration, or the introduction of NO_2 groups supplied by nitric acid into the cellulose molecule. In this reaction sulphuric acid is present as a catalytic agent. The nitration is performed in steel tanks known as mechanical dippers, the cotton being introduced on the surface of the acid mixture and immediately submerged by rotating paddles. After the nitration has proceeded for the required length of time the entire mixture of cotton and acid is discharged into a centrifugal wringer where most of the acid is removed from the nitrated cotton. This acid is recovered for reuse. Following the acid removal the cotton, still containing a considerable quantity of mixed acid not removed by the centrifugal action of the wringer, is boiled with frequent changes of water in large wooden tubs. This boiling and washing is carried on until very delicate chemical tests show that the nitrocellulose has attained a chemical stability sufficient to insure extremely long life of the product made from it. Starting with the crude linters and ending with the nitrated cellulose of pyroxylin, it requires about 200 gal. of water in the chemical treatments given each pound of cotton, and several days are required for the complete cycle.

The pyroxylin is now at a stage where it is readily soluble in the various solvents mentioned above, but still contains on the surface and in the microscopic canals of the fiber a

large amount of water that must be removed before mixing the cotton with the solvent. This removal of water, or dehydration as it is termed, is accomplished by the displacement of the water with alcohol in large hydraulic presses. Alcohol mixes readily with all of the solvents used in the pyroxylin industry, and therefore the cotton containing the alcohol can be employed in any type of solution we may wish. It will be noted that in the cycle outlined above the pyroxylin is never dry at any point. As water is removed it is automatically replaced with alcohol, and in this manner there is no particular hazard in handling the product.

Method of Using Pyroxylin in Liquid Enamels

Pyroxylin as prepared above is then dissolved in amyl acetate, for instance, and the solution filtered. This type of solution, either by itself or mixed with a small amount of gums or resins, is a type of clear lacquer used for depositing a transparent, almost invisible coating on highly polished silver, brass or other objects to protect the metal from tarnishing. Such lacquers resemble glycerin in consistency, but perhaps are slightly yellow in appearance as compared with pure glycerin. This type of lacquer was the original use of soluble pyroxylin in industry.

A later development involved the incorporation in such lacquers of finely ground pigments which produced a very popular product known as pyroxylin enamels. Such objects as bathroom fixtures, metal and wooden pencils, metallic lamp stands and hardware on closed automobile bodies are commonly finished with these pyroxylin enamels. The solvents used for pyroxylin are readily volatile at room temperature, and a coat of such an enamel dries with a speed that at first acquaintance seems almost incredible. When a film of this liquid enamel is exposed to the air these solvents immediately begin to evaporate, and in a short time have gone off entirely in the air. This leaves a hard, tough film of pyroxylin containing therein the minute particles of pigment, and once the solvents have evaporated no further change takes place. The pyroxylin and the pigment just as they were put in the mixture are now on the surface of the object being coated.

Pyroxylin as Body Enamel Conceived in California

The first commercial use of pyroxylin products in the automobile refinishing industry was the employment of a very high-grade expensive type of pyroxylin enamel in certain refinishing shops in California. Pyroxylin solutions at that time were mainly volatile solvents, the actual amount of pyroxylin or other solid materials in them being relatively small. This meant that to deposit from such a solution a film of sufficient hiding power to produce the solid built-up color desired, such a great number of coats was necessary that the process was not a practical one. When an attempt was made to increase the amount of pyroxylin in the solution to give it more covering power, the viscosity increased to such a degree that the solution was too stiff to work. Finally, a method was discovered which permits putting into the solution at least three times the amount of pyroxylin, which is the film-forming constituent, and the big obstacle had been surmounted. After nearly 2 years more of intensive work in the duPont laboratories and in the Oakland factory, practical methods for the use of colored pyroxylin enamel in the automotive industry were perfected.

For information on the advantages of pyroxylin enamel, its durability, methods of application, cost and time data and many other points, readers are referred to the report of the Detroit Meeting on p. 90 of the January issue of The Journal. Many of the questions asked at the Cleveland meeting were the same as those answered at Detroit and they are also covered in the aforementioned report. New points brought out in the discussion at Cleveland are set forth in the following paragraphs.

Many questions related to the use of pyroxylin enamels for refinishing. Mr. Flaherty said that it is necessary to remove all varnish and paint from a used-car to do satistory refinish work with pyroxylin enamels. There is too much risk of the pyroxylin solvents forming soft spots in those parts of the old varnish coat which may not be fully oxidized. After the metal is properly cleaned, it should be coated with the customary oxide primers. It is extremely important that these primers be fully oxidized before the enamel is sprayed on. Drying ovens are not essential provided sufficient time is allowed for thorough oxidation of the primer coats.

Varnish or Rub-Out to Secure Luster?

Opinion was divided as to whether or not finishing varnish should be applied over the dull pyroxylin enamel coats to secure a glossy finish. A representative of the Moon Motor Car Co. said that he had exposed panels finished with varnish for 6 or 8 months without any failure of the finish coat. Mr. Flaherty said that the duPont company does not recommend varnishing over the pyroxylin enamel. While the life of the varnish is longer than it would be over color varnish, the finish seems to look worse when it fails finally. Rubbing seems to be the ideal method to secure a glossy finish. Oakland open bodies are given a glossy finish with 2 hr. of rubbing. William Cox of the Cleveland Automobile Co. said that his experience with varnish over pyroxylin enamels has been unsatisfactory. He attempted to refinish varnished bodies by spraying pyroxylin enamel on top of the failed varnish but found this impractical. To remove the finish varnish from the pyroxylin coats without harming them, he used a strong ammonia solution. Mr. Cox related how one of his men had used Bon Ami to clean a pyroxylin enameled body and found that each successive wiping off of the dried powder produced a higher luster on the finish.

Edward Payton of the Cleveland Used Car Bureau said that the new finishes would be a boon to the merchandiser of used-cars. Almost every used-car must now be repainted before it is salable.

Checking or failure of pyroxylin enamels in service may be due to any one of four causes, said Mr. Flaherty. First, the undercoats may not have been properly prepared and oxidized; second, the enamel coats may have been too heavy; third, the enamel may have been sprayed on too dry due to the use of too great spray pressure, or to the operator standing too far from the body; fourth, the enamel may have been allowed to settle in the container until that portion at the bottom became too heavy for satisfactory use.

Pyroxylin enamels cannot be used to finish heated parts such as exhaust-manifolds. They decompose rapidly when they reach their critical temperature which is in the neighborhood of 140 deg. cent. (284 deg. fahr.).

JOINT MID-WEST-MILWAUKEE MEETING

Braking demonstrations will be featured at the big joint meeting of the Mid-West Section and the Milwaukee group at Milwaukee on March 14. W. S. James, of the Bureau of Standards, will be present to test the effectiveness of both two and four-wheel brakes with the decelerometer developed by the Bureau. After the tests, which are scheduled to begin at 3 o'clock, dinner will be served at the Milwaukee Athletic Club.

The evening technical meeting will take up four-wheel brakes from both the mechanical and the hydraulic angles. A. Y. Dodge, of the Perrot Brake Corporation, will be one of the speakers, and a representative of the Four-Wheel Hydraulic Brake Co. will also present a paper.

DOUBLE BRAKE BILL FOR WASHINGTON

Brakes are a popular March topic. On March 7, at 2 o'clock, the Washington Section will have an opportunity to see a demonstration of brake performance conducted by W. S. James, of the Bureau of Standards. Records of performance will be taken with the decelerometer developed by the Bureau. Tests will be made on both wet and dry streets to determine the possibility of skidless stops.

At the Cosmos Club, at 8 p. m., Mr. James will explain

the theory of brake operation and present the results of tests of different kinds of brake on various types of car. He will compare two and four-wheel brakes on the basis of actual performance under a variety of road conditions. City traffic regulations with regard to brakes will also be considered and emphasis laid on the importance of reasonable requirements.

OIL MUST SUIT INDIVIDUAL ENGINE

E. B. McCartney Analyzes Factors in Correct Lubrication at Minneapolis Meeting

E. B. McCartney

As probably more than 50 per cent of operating trouble with automotive engines is due to incorrect lubrication, E. B. McCartney, of the Vacuum Oil Co., treated in detail the important subject of Correct Lubrication at the meeting of the Minneapolis Section on Feb. 6.

In beginning his talk, which was illustrated with many slides, Mr. McCartney reviewed the three functions of a lubricant in an automotive engine: First, to form and maintain a film between the moving parts; second, to aid in sealing the pistons against blow-by and third, to transmit heat. Correct lubrication is attained when the right grade of a high-quality oil is used correctly and the oil in the engine is kept in good condition.

There is no formula for quality, and no test other than actual use of the oil in an engine. Oil specifications and oil tests have their value in certain cases, but they alone do not determine quality in a lubricant.

Right Grade of Oil Important

It is just as important to select the right grade of oil for any particular engine as it is to use a quality oil. The heavier grades of oil are somewhat higher in lubricating value, but they do not flow freely at most temperatures. For extremely low temperatures, the lighter grades of oil will flow freely and be distributed where the heavy grades will not, and for this reason it is common practice to specify somewhat lighter grades for winter use. The choice of the correct grade of oil for any engine involves an analysis of that engine, with special consideration of four important factors: Heat, the distribution system, piston seal and carbon.

Each of these factors was taken up in turn. According to Mr. McCartney, service is the most important consideration affecting the operating temperature of the engine. The method of cooling also influences to a great degree the normal operating temperature. In the case of the water-cooled engine, the temperature of the water in the jackets cannot rise above 212 deg., with a corresponding low temperature in the combustion-chamber; but, in the case of the air-cooled cylinder, combustion-chamber temperatures may be very high. Other factors influencing the operating temperature of the engine are its size, speed, valve arrangement and principle of operation.

Distribution System Affects Choice of Oil

The oil distribution system may be of two types, splash or force-feed. In the first, the oil reservoir is outside of the engine and arranged to feed oil into the dipper troughs as fast as it is used up in the engine. Splash alone is depended upon for distribution to the bearings and the wearing surfaces, and since heavy oils do not atomize readily, the lighter grades of oil are naturally selected for systems of this kind. In the force-feed system, the reservoir is contained in the engine and the oil is pumped under pressure to the crankshaft and the connecting-rod bearings. Atomization is accomplished by forcing the oil out through the narrow clearances at the ends of the connecting-rod bearings, and it is distributed over the cylinder walls by the centrifugal force of the whirling crankshaft. The oil is atomized mechanically and any grade can be used.

Not only the type but the oil-pump and the screen of the lubricating system must be examined to make sure that they will handle the oil at all operating temperatures of the engine. An oil-pump elevated high above the oil reservoir, with a long exposed suction line leading from the reservoir and ending in a small, fine-meshed screen, obviously could not distribute the heavier grades of oil, especially in cold weather. Where the pump is located inside the engine and submerged in the oil, it is always primed and will handle the heavier grades of oil, even at low temperatures, if the screen is large and of rather coarse mesh.

The third factor in the analysis of the engine is the piston-ring seal. Oil alone cannot insure a perfect seal. On the other hand, the most perfectly fitted piston will not be tight without oil to fill the fine clearances and inequalities of the finish. Without a perfect piston-ring seal, blow-by of the compressed gases and of hot explosion gases on the back stroke occurs. Leakage of the compressed charge past the piston on the compression stroke results in the dilution of the crankcase oil with fuel, under-lubrication of the cylinder walls, loss of power and loss of pull. On the back stroke, the engine suffers again from loss of power and the hot gases passing the piston further reduce the lubrication of the piston and the cylinder walls.

Too Heavy Oil Means Carbon Knock

The fourth and last factor is carbon. Carbon formations and troubles associated with them are intimately bound up with troubles from blow-by, dilution and oil-pumping. In general, carbon formations result from excessive amounts of oil in the combustion-chamber. The lighter grades of oil will burn clean at moderate temperatures, but it requires greater heat to burn clean the heavy grades of oil. If these grades are used in engines running at only moderate temperatures, large deposits of carbon will result. On the other hand, in engines operating at high temperatures, as in airplanes and tractors, the heavier grades of lubricant can be used without ill effects because enough heat is generated to burn up all the oil. Carbon in the engine results in the rings and the valves sticking and gumming, but it is most obnoxious when it produces the so-called carbon knock. This knock is not, strictly speaking, caused by carbon, but deposits of carbon produce conditions under which the knock takes place.

After this consideration of the four factors that determine the correct grade of oil for any particular engine, it is possible to formulate a sort of rule for guidance. Since the heavier grades of oil are somewhat richer in lubricating value, use the heaviest grade of oil that the circulating system can properly distribute, which will not leave an obnoxious carbon deposit and which will properly seal the pistons against blow-by. Since the kinds of engine are many and the grades of oil few, it may be necessary at times to compromise between the design of the engine and the performance of the oil. But it is always possible to select a grade of oil that will give ample lubrication and at the same time will not cause trouble from carbon deposits or from lack of distribution.

Maintaining Oil's Quality in Use Imperative

After an oil of the proper quality and grade has been selected, the third item in securing correct lubrication is the proper use of the oil and the maintenance of its quality in the engine. Oil should be replenished at frequent intervals and the level of the oil should be kept up at nearly full at all times. Frequent additions of fresh oil maintain the

quality of the lubricant in the crankcase and prevent excessive dilution. As the crankcase oil becomes contaminated by road dust, worn metal particles, carbon, water and fuel, it is necessary to drain off and refill the reservoir with fresh oil at intervals of from 500 to 1000 miles of travel. It has been common practice to flush out the crankcase with kerosene after draining the old oil, but this is not good practice, as it is impossible to get all of the kerosene out of the engine, resulting in the dilution of the new oil. The proper method is to drain the engine when hot and the warm thin oil will amply flush the crankcase.

Common Lubrication Difficulties

The most common difficulties experienced in the lubrication of automotive engines are crankcase-oil dilution, scoring and bearing failures, sludge and water troubles, oil-pumping and carbon.

Crankcase-oil dilution results from an excessive use of the choke, too low operating-temperature, inefficient combustion, leaky piston-rings, rich adjustment of carbureter, flushing with kerosene and using the wrong grade of oil. Excessive use of the choke or an overly rich carbureter setting both result in flooding the combustion-chamber with raw fuel that is blown past the pistons. When the combustion is inefficient, all of the mixtures are not burnt and some remain to be blown past the pistons. Running an engine cold acts in the same way as when there is not heat enough to burn up all of the fuel.

Sludge is a thick, jelly-like substance found in an engine crankcase in cold weather. It is a mixture of oil, water and worn-metal dust or carbon. The sludge causes considerable trouble by freezing and stopping the oil supply and can be removed from the crankcase only by lowering the pan and cleaning out by hand. To prevent the formation of sludge, it is necessary to prevent the accumulation of water in the crankcase. The water which is almost always found there during cold weather comes from above the piston in the form of steam that condenses in the cold crankcase. To prevent the accumulation of sludge, the water should be drained from the crankcase every day and a small amount of alcohol added to prevent freezing.

Oil-pumping may be defined as the passing of oil into the combustion-chamber faster than it can be consumed. This, of course, tends to the formation of excessive amounts of carbon, fouling of the spark-plugs and general dirtiness of the engine. The remedies for oil-pumping are the installation of new pistons and rings, reduction of the oil supply in splash lubricating systems, taking up of bearings in force-feed systems, and the proper drainage of the pistons.

Piston scoring and bearing failures are well-known troubles and the remedies are obvious. Some of the oil companies advocate the use of heavier oils for worn engines, followed by medium, and recommend that the correct grade for an engine is a heavier grade for each year of service. Mr. McCartney pointed out the fallacies of this method of selecting the correct grade of oil for any particular engine by reminding his audience that with a lack of lubrication, abuse, poor materials and a faulty design, an engine may be completely worn out at the end of 6000 miles, while another engine with correct lubrication, care, the best of materials and a good design, may show very little wear at the end of 35,000 or 40,000 miles of use. As the heaviest grade of oil that the lubricating system will handle without forming carbon deposits is already in use, to go to a heavier grade of oil later would be to risk a lack of distribution.

In closing his talk, Mr. McCartney pointed out that the greatest possible saving through the use of cheap lubricants would be perhaps $10 or $15, while the repair item might jump to hundreds of dollars. Only by correct lubrication can the maximum amount of service and satisfaction be obtained from an engine.

At the next meeting of the Minneapolis Section on March 5, L. O. Grange will speak on Analysis of Design and Adaptability of the Low-Pressure Tire. The meeting will begin at 8 o'clock at the Manufacturers Club, Builders Exchange, Minneapolis.

PRODUCTION ASPECTS OF BALANCING

Packard, Cadillac, Northway and Others Contribute to Detroit Section Program

Balancing of engine and chassis parts is now being effected in production by some car builders to a degree deemed impractical less than 5 years ago. Crankshafts are being balanced both statically and dynamically within very close limits. Pistons, rings and connecting-rod assemblies are being carefully selected and grouped in engines with regard to their relative weights. Even the clutch and the propeller-shaft assemblies are being tested to eliminate disagreeable vibration due to unbalance. These and many other interesting facts were brought out at the meeting of the Detroit Section of Feb. 21 when production aspects of the vibration problem were discussed in a symposium of six valuable papers. These papers are given in abstract form in the following paragraphs.

Balancing of Engine Components

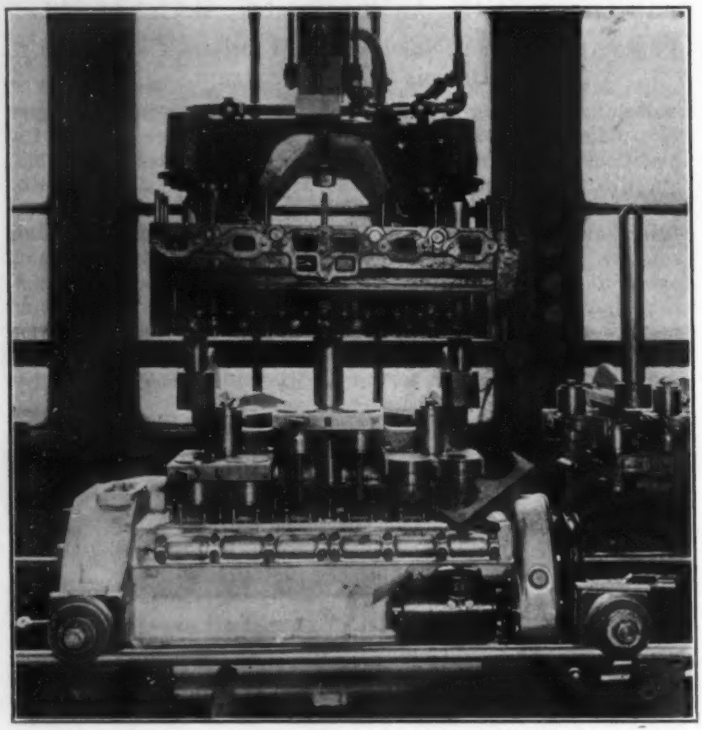
A. A. Bull, chief engineer, Northway Motor & Mfg. Co., analyzed the effect of static and dynamic unbalance of engine parts on vibration. He said that static unbalance of the crankshaft is not really important in itself, but dynamic balance cannot be obtained without it. Not so long ago, and particularly with crankshafts machined all over, it was considered sufficient to establish static balance only, but this can hardly be considered a satisfactory method because there is no guarantee of equal distribution of weight along a crankshaft forging. Flywheel and clutch parts can be satisfactorily balanced statically only, as they are not likely to be affected dynamically to any great extent on account of their short axial dimensions, but in checking and rectifying for static balance, a considerable dynamic error can be introduced into the flywheel if the material is drilled out on one side of the wheel only, which is frequent practice. In correcting for static balance, equal material must be removed from both sides of the vertical axis of symmetry of the flywheel casting. Flywheels and crankshafts should preferably be balanced separately. With reasonable accuracy in the flange and the pilot of the crankshaft and the flywheel respectively, the run out will not be sufficient to introduce any serious unbalance.

Torsional Vibration Problem

The greatest problem in six-cylinder engines is the existence of the critical periods attributed to torsional vibration of the crankshaft. These exist regardless of the mechanical balance of the parts. The shaft is twisted due to the forces imposed upon it by the expansion stroke, disturbing the relationship of the crankpins and setting up an oscillation. Torsional vibration is also produced at higher speeds by the inertia forces of the pistons and the rods themselves. Shaft vibration arising from the inertia torque can be minimized by a reduction in the weight of the pistons and the rods. Variations of pressure in the cylinder will change the torque reaction more than a variation in the weights of the parts themselves.

Torque-recoil balance, that is, the tendency of the engine to rotate about the shaft axis, is not affected by any combination of pistons and connecting-rods and applies to all engines. This vibration will be affected by the weights of the parts to some extent.

Summing up the general situation, Mr. Bull said that an engine in theoretical balance should have the reciprocating and the rotating parts balanced to close limits, but a more definite understanding of how this should be accomplished is unquestionably desirable. The manufacturing department in many cases does not recognize the extent to which the engine balance is affected by dynamic errors in the crankshaft and the weights of the parts. On the other hand, the equipment that is available for the balancing of these parts is usually of a complicated nature and does not lend itself to rapid production or fool-proof results. In the case of balancing machines that do not record the actual unbalance, there is no guarantee of uniformity even though a balanced



PACKARD CYLINDER AND CRANKCASE ASSEMBLY FIXTURE

The Cylinder-Block Assembly Is Clamped to and Supported by a Fixture Which Slides upon the Cylindrical Posts Shown in the Background. Vertical Movement of the Fixture Is Controlled by an Air-Hoist. Split Clamps Are Placed around Each Pair of Pistons To Tie Them Together as a Rigid Unit and Prevent Distortion of the Connecting-Rods. The Clamps Also Serve To Close the Piston-Rings as They Slip into the Cylinder Bore. One of the Clamps Is Shown Open on the Right-Hand Pair of Pistons. As the Operator Opens the Valve Controlling the Air-Hoist, the Cylinder-Block Is Lowered and Guided Accurately into Place until All of the Pistons Have Passed into the Cylinders. The Three Piston Clamps Are Removed Just Before the Cylinder-Block Reaches Its Seat on the Upper Face of the Crankcase

sample is used for a standard. Balancing of the engine components is really essential and reasonable limits or tolerances can be established and regularly adhered to in commercial production.

BALANCING METHODS USED IN THE PACKARD SHOPS

L. L. Roberts described balancing as practised by the Packard Motor Car Co. Packard crankshafts are balanced both statically and dynamically by grinding off uniform layers of metal from the flat side of certain of the crank arms. Two arbitrary planes are selected in which to correct any unbalance of the eight-throw shaft. Stock is allowed on only four of the crank arms so that the unbalance can be restricted to the quadrant bounded by the two arms at each end, thus allowing all of the correction to be made on these arms. The Newkirk type of balancing machine is used and with the aid of a simple chart the balancing-machine operator marks the thickness of stock to be removed on the sides of the crank arms on which the grinding operations are to be performed.

It was found that flywheels accurately machined all-over showed negligible dynamic unbalance if put in perfect static balance. The flywheels are balanced on a Crawford vertical-type balancing machine within a limit of error of ¼ oz-in.

Connecting-rods for Packard engines are selected in sets, the individual rods of which are alike within plus or minus ⅛ oz. both for total weight and center of mass. To give proper firing balance by making the intensity of the power impulses as nearly equal as possible, the combustion-chambers in the Packard cylinder-head are fully and accurately machined to have equal volume by a specially-designed automatic profile-milling machine. A roughing and a finishing cut are taken to insure smooth surfaces as these greatly deter carbon formation.

To insure against breaking the piston-rings and distorting the pistons and the connecting-rods when assembling the cylinder to the engine, Packard production engineers developed the interesting assembly fixture shown herewith. The cylinder-block assembly is clamped to the fixture and is supported by an overhead air-cylinder hoist. As it is lowered onto the crankcase it is guided by the fixture sliding on the cylindrical posts shown in the background, thus being practically piloted into place. Removable clamps are placed around each pair of pistons as shown, to protect the rings and guide them into place. These clamps also prevent springing of the pistons and the rods.

The outer drum, the inner drum and the backing plate of the Packard clutch are accurately balanced on parallel balancing ways. It is almost impossible to detect unbalance of the complete clutch unit until it has been assembled to the transmission and tested. About the only way to correct clutch unbalance when encountered is to remove the complete assembly and replace it with another.

PROPELLER-SHAFT BALANCE IS IMPORTANT

A testing machine for detecting unbalance of propeller-shaft units is used at the Packard shops. The test consists of first noting the run-out of the propeller-shaft when rotated in the machine by hand. If it is within the prescribed limits, the shaft is then rotated at a speed of 600 r.p.m. and the tailstock slide of the machine is worked backward and forward to free the splines and trunnions of the universal-joints. Next the tailstock is locked and the shaft is driven throughout the entire speed range of the car as indicated by a standard speedometer mounted on the testing machine. If any unbalance is present, it is manifested through a disagreeable buzzing sound and a chattering of the tailstock. No satisfactory method has been found for correcting unbalance of the propeller-shaft assembly and the rejected units are returned to the vendor. Mr. Roberts concluded his remarks with the suggestion that balancing machines should incorporate proper metal-working machine-tools so that corrections for unbalance can be made without removing the part being balanced from the machine.

CADILLAC SHAFT BALANCED WITH RECIPROCATING PARTS

Balancing practice in the Cadillac Motor Car Co. plant was described in a paper by D. E. Anderson. He called attention to the article by E. W. Seaholm in the January, 1924, issue of THE JOURNAL, which covered the theoretical side of the Cadillac crankshaft design. In that article it was pointed out that the Cadillac crankshaft is not in running or dynamic balance until assembled with the pistons and the connecting-rods. It is necessary, therefore, to apply equivalent weights on each of the crankpins when balancing the shaft on a dynamic balancing machine. These weights are made in the shape of split rings that are clamped around the crankpins. The weights are designed to compensate for the reciprocating and the rotating parts together with the volume of oil that is carried in the crankpin. Much care must be exercised in the design and the manufacture of these balancing rings for the following reasons: first, their weights must be identical; second, they must be constructed so that their application to the shaft takes a minimum of time; third, it is necessary to harden them to withstand wear and possible deformation; and fourth, they must be in static and dynamic balance so that their centers of gravity will lie exactly on the center line of each crankpin and also in the correct axial position on the shaft.

Because of the nicety of the balance of the shaft in combination with the rotating and the reciprocating parts, it is obvious that selection of the pistons, the rods and similar parts must be made so that the combined weight of each assembly is identical within practical limits. Otherwise, all advantage derived from balancing would be lost. Variations between the weight of the several assemblies in the Cadillac engine lies within the tolerance of plus or minus ⅛ oz. To facilitate selection, each part is weighed and marked in hundredths of a pound, accurate within 0.004 lb., and then stacked in separate piles according to weight. The assem-

bler works from a chart so that he can pick out the proper combination of weights to make a complete assembly come within the accepted limit.

Four counter-weights, two large and two small, are applied to the Cadillac crankshaft. The end counter-weights are altered to correct dynamic unbalance and the intermediate counter-weights are drilled for static unbalance. The weights are made over-weight purposely to allow sufficient metal to be removed by drilling into them; otherwise, metal would have to be removed from the shaft itself, thus spoiling its appearance and making it necessary to resort to grinding. An upright drilling machine, fitted with a dial attached to the feed mechanism to indicate the exact depth of the drilled hole, is set up beside the balancing machine. The Cadillac shaft is balanced within a minimum of 1/8 oz. at a 4 1/4-in. radius for both static and dynamic balance. Special care is taken to instruct Cadillac service-stations on the need of carefully selecting replacement parts according to weight; otherwise, the delicate balance of the shaft and the several assemblies of rod and pistons would be disturbed.

Flywheel, Clutch and Propeller-Shaft Balanced

The Cadillac flywheels and crankshafts are tested for unbalance separately. The flywheels are put in static balance but are not tested for dynamic balance. With regard to balancing the other units of the car, Cadillac practice is much the same as that set forth by Mr. Roberts in his description of Packard methods. Attention is given to clutch parts and universal-joint assemblies. The latter are tested on a machine that rotates them up to 3000 r.p.m. A load is placed upon the shaft by a brake. If a noticeable whip occurs, the assembly is returned to the vendor and he is able to correct many shafts by giving them a slight bend in a direction opposite to that produced by running. The bending method sounds rather crude, but it has proved to be a practical remedy. Mr. Anderson recommended that the builders of balancing machines should give some thought to the balancing of flexible rotating bodies such as tubular propeller-shafts.

Accurate Forging Facilitates Balancing

Harold F. Wood, chief metallurgist of the Wyman-Gordon Co., read an extremely interesting paper on the production of crankshaft forgings. He said that in the early days of the industry it was only required that the crankshaft have sufficient strength to resist the fatigue of service and such accuracy of shape as would allow machining to the finished dimension at reasonable cost. Today two other factors of equal importance are demanded; first, a design of crankshaft to reduce vibration and enable dynamic balance to be easily obtained; and second, a reproduction of this design in the forging with such accuracy as to facilitate quantity production. He outlined the many points that demand careful attention throughout the production of the crankshaft forging to meet these two demands. After the shaft has been forged, heat-treated and approved from the standpoint of necessary physical properties, it passes to a department that determines accuracy in centering, in alignment and in index. Unless the centering operation is performed so that the axis as determined coincides with the theoretical axis of the shaft design, the resulting crankshaft will be out of balance. It is impossible on any rough forging to center the crankshaft accurately on the theoretical axis, but with proper equipment this eccentricity can be reduced to a minimum. To accomplish this, six and eight-throw crankshafts are placed in a mass centering machine of special design at the Wyman-Gordon plant. The machine indicates the index of all pins and the length of throws simultaneously to the operator. The crankshaft is adjusted by the operator to give the best possible index. The starting point is then marked on the shaft in a location that will be best suited to the machining operations of the engine builder. After the best possible index and starting point are determined, the crankshaft is then centered on the axis determined by this operation.

In the Wyman-Gordon laboratories there is a special machine for testing crankshaft design which reflects very closely the performance of the crankshaft in the finished engine. The crankshaft is mounted in this machine in bearings identical with those of the engine, but it is not held rigidly in place, being free to register deflection at various speeds. This machine is capable of operating at the high speeds in general use today and records accurately by electrical contacts the deflection of the shaft at such critical speeds as are being studied.

Balancing-Machine Builder Comments on Balancing

Comments on balancing from the viewpoint of a builder of balancing machines were given by Jacob Lundgren. He recommended drilling as the most economical method of removing metal for balancing purposes. Milling is slow in comparison with drilling and uncertain as to the weight removed. Grinding is not only uncertain, but the heat generated by the grinding operation is transmitted to the shaft and may cause some deflection or springing so that straightening will be required. Extreme unbalance in crankshafts is generally due to errors in the location of the center of the crankshaft forging. Much of the trouble is due also to variation in the angular position of the crankpins or to errors caused by wear in the dies. It is advisable to machine a number of shafts, say 10 or 12, from a set of dies and check them for balance before starting a large production. If the unbalance is fairly uniform as to amount, plane and location, corrections can be made in the dies to add metal where required to bring the unbalance down to a small limit. Mr. Lundgren expressed a preference for plane bearings instead of rollers to support the shaft during the balancing operations. Long shafts, such as six-cylinder or eight-cylinder shafts, should have a center support to prevent errors due to whipping. The center bearing of a shaft should not have an eccentricity of over 0.001-in. radius.

It is extremely difficult to balance clutches. The housing, or parts connected to the flywheel and revolving with it, can be balanced as a unit with the flywheel. The plate and rings or stamped parts, although of uniform weight, will sometimes be unbalanced due to eccentric mounting. The amount of unbalance in an assembled clutch will vary when the clutch is in operation due to changes in the relative position of the driving and the driven members. Mr. Lundgren joined with the other speakers in urging careful balancing of propeller-shaft and universal-joint assemblies. He also spoke briefly on the selection of reciprocating parts by relative weight to avoid unbalance. The practice of making the two opposite pistons on a pair of cranks of the same total weight should not be followed. It creates an unbalance by introducing a dynamic couple. Unbalance caused by unequal cylinder compression-pressures may in some cases amount to several pounds. An assembled engine that does not show unbalance of more than 8 oz-in. when tested as a unit on a balancing machine may safely be expected to run without any marked vibration on the testing stand.

W. R. McDonough, of the Gisholt Machine Co., gave a brief illustrated talk describing the balancing machine built by his company. After the adjournment of the meeting, this machine was demonstrated and great interest was shown by the members in the explanation of its use.

"BALLOONS" FOR PENNSYLVANIA

Members in Pennsylvania Section territory will surely be interested in the first of the fine meetings planned for the remainder of the season. On March 11, J. E. Hale, of the Firestone Tire & Rubber Co., will present in detail the "balloon tire," the popular name for the new tire development that provides air-cushion comfort by using low-pressure air and a larger area of contact than in the ordinary tire. Mr. Hale will illustrate his talk with slides.

The meeting will be held at Kugler's Restaurant, 34 South 15th Street, Philadelphia. A dinner at 6:30 p. m. will precede the meeting at 8 o'clock.

ENGINE LUBRICATION NEEDS STUDY

Viscosity, Temperature Control, Dilution, Strainers and Filters Topics at Buffalo

A. LUDLOW CLAYDEN

Engine lubrication is a fertile field for automotive research. This was reflected by the papers and discussion at the Buffalo Section meeting on Feb. 4. L. H. Pomeroy and A. Ludlow Clayden took opposite sides of the question Engines for Oil vs. Oil for Engines. Their papers are printed in full in this issue of THE JOURNAL beginning on p. 307. The lack of definite fundamental information and the great difference of opinion in evidence at this meeting indicated that it is an opportune time for automotive and lubrication engineers to inaugurate a new regime of cooperative study on automotive-lubrication problems similar to that which has proved so productive in the study of fuel volatility. The points brought out in the discussion of the two papers are reported briefly in the following paragraphs.

W. S. James, of the Bureau of Standards, called attention to the vagueness of the present-day oil specifications. He also added to Mr. Pomeroy's criticism of viscous oils as automotive-engine lubricants by stating that it takes as much power to overcome engine friction at a speed of 20 m.p.h. as it does to propel the car itself. Mr. James commented on the importance of controlling oil temperatures as a means of maintaining some degree of uniformity in the viscosity of the lubricating oil. It is also important that the refiners maintain the viscosity and physical properties of lubricating oils within reasonable limits when their trade names are supposed to designate these qualities.

NEED FOR OIL-TEMPERATURE CONTROL

George A. Round, of the Vacuum Oil Co., in a contributed discussion of Mr. Pomeroy's paper, agreed that the effect of oil viscosity on engine efficiency should be considered when recommending lubricants. He did not consider the tests made by Mr. Pomeroy as truly indicative of service conditions since they did not take proper account of the changes in the viscosity caused by dilution. He suggested that Mr. Pomeroy repeat his tests with 5, 10 and 15 per cent of kerosene added to the lubricating oils. The need of temperature-controlling devices has been conclusively proved by Mr. Pomeroy's tests and such devices would be of great value in reducing dilution. Test work of the Vacuum Oil Co. indicates that oils of low viscosity possess adequate lubricating value to meet practically all operating conditions even when diluted considerably. This organization considers four factors when recommending lubricating oils to meet automotive requirements: first, operating temperatures; second, oil distribution; third, mechanical efficiency as affected by sealing qualities, dilution and friction losses; and fourth, carbon sensitiveness. Oils having a greater viscosity than 60 sec. at 210 deg. fahr. are seldom recommended for passenger cars and trucks. Mr. Round stated that specification charts of many American, British and Continental manufacturers showed that the large percentage of engineers favor oils of much higher viscosity than those recommended by Mr. Pomeroy. Owners and garage men also favor oils of high viscosity.

UNIQUE DEVICE FOR COMPARING VISCOSITY

A simple instrument for checking oil viscosity was described by W. R. Gordon of the Pierce-Arrow Motor Car Co. This device consists of a pair of parallel glass tubes, one of which is long and the other short. The short tube is filled with fresh lubricating oil except for the presence of a small air-bubble. The diluted oil to be tested is poured into the longer glass tube, filling the latter except for the presence of a similar air-bubble. The two tubes are then sealed so that when they are inverted the air bubbles will rise through the columns of oil. If the air bubble in the tube of diluted oil reaches the top of its tube before the similar air-bubble rises to the top of the tube of fresh oil, it is an indication that the viscosity of the diluted oil has become too low to insure adequate lubrication.

Mr. Clayden stated that most of the present-day tests and specifications for lubricating oils are meaningless and useless to the average man. Automotive engineers could help considerably by establishing some standard method of treating fresh oil so that it could be put into a condition very closely approximating that which it would have after a definite period of use in an engine. None of the present-day tests really do this. Lubricants of today are in a condition from the scientific point of view similar to that of steel 25 or 30 years ago. At that time, little was known about some of our present-day alloys. Microscopical study of lubricants may lead to some results as valuable as those which have been reached by microscopical study of steel. Mr. Clayden believes that the tendency of an engine to dilute is more dependent upon the design and construction of the engine than upon the character of the fuel. He has conducted tests on the freezing of condensed water in the crankcase oil which have led to the conclusion that water will remain in the oil unless its temperature is raised to above 100 deg. fahr.

The popularity of oils of high viscosity is due in part to the public's desire to quiet noisy timing-gears and engines, in Mr. Pomeroy's opinion. As usual, the public will pay heavily for silence. Mr. Pomeroy commended Mr. Gordon for the design of his simple viscosimeter, stating that this was an example of a simple workshop instrument which could be used by the layman. He agreed with others present that thermostatic temperature control of the lubricating oil is needed. If a simple method of doing this can be developed, friction will be reduced and dilution will be reduced, due to the natural distillation of the lighter ends of the diluent from the hot oil.

David Beecroft addressed the annual get-together dinner of the Buffalo section on the evening of Feb. 29. He discussed the function of automotive vehicles in the Nation's transportation system.

PROSPERITY AND AMERICAN CONSUMING POWER

THE most powerful steadying influence of an economic nature in the entire world today is the enormous consuming power of the American people. Apart from certain foreign areas, where for special reasons of a well understood nature the general economic movement of mankind has not been participated in during the past 12 months, it is equally undeniable that the only conclusion to be drawn from a dispassionate comparison of economic conditions throughout the world as they are at the end of 1923 with what they were at its beginning is that immense gains have been made in the course of the year in respect of all the essential economic activities by which the world's peoples live and thrive. And in the attainment of this result no single influence has been more potent than the continuously increasing consuming power of the American people, ever supporting American industry and trade at full capacity, strengthening the markets for raw materials and other essential products in every part of the earth, stimulating the flow of commerce in every direction and serving as the *point d'appui* for the resumption of that confident production of all sorts that supplies the wherewithal for all the innumerable interchanges of goods and services that are a condition precedent of economic and social welfare everywhere.

The productive capacity of American industry was not so enlarged as a result of the war conditions that it now much exceeds the consuming power of the American people. As regards industrial production, we have to guide us the monthly index of production in our basic industries that has been computed by the Division of Research and Statistics of the Federal Reserve Board since 1919. Upon examination of the successive index numbers for the first 10 months of 1923, we find that industrial production in this Country during the past year has been considerably more than 20 per cent greater than it was in 1919 and almost 20 per cent greater than it was in 1920. Yet in the "boom" period of 1919 and 1920 no complaint was heard that our industrial plant exceeded the needs of the Country. Nor can it be argued that this huge industrial production in the United States in 1923 has not been a true reflection of the consuming power of the American people, either on the ground that the year's exports of industrial products were exceptionally large or on the ground that unsold goods are known to have accumulated in large quantities in all directions. All the available statistical evidence, in fact, indicates that in the main the enormous consuming power of the American people has provided a profitable market for the Country's unprecedented industrial production in 1923, and that the question of adequate foreign outlets for our surplus production has been essentially academic rather than of immediate practical importance.—Arthur Richmond Marsh in *Economic World.*

HIGHWAY CONSTRUCTION

HIGHWAY engineering and transportation, or the construction and the operation of the highway, is not a theoretical or academic subject, but a vital part of our economic social life. We are spending each year in this Country $1,000,000,000 for road construction, while the demand for more high-type road is insistent and growing. The investment in motor vehicles in round figures is $10,000,000,000 and the annual operating cost of these vehicles is some $6,000,000,000 or $8,000,000,000 more. With an investment and annual expenditure of this magnitude, can anyone doubt the need of a practical study of the economics of highway construction and operation? This is the field of highway research.

At the last meeting of the Advisory Board of Highway Research, Director W. K. Hatt said that in the last 3 years much progress has been made in quickening the will to research, in mobilizing the energies of research agencies and in assembling the data necessary for judgment upon questions of highway planning, construction and operation. At present a well-trained and experienced highway engineer, in possession of available data, can select a type of highway suitable to the conditions of climate and traffic of a given situation, can specify the materials and design the section with a reasonable certainty that it will withstand the specified conditions of service. The communication of these data to engineers in general has not kept pace with the accumulation of the data, nor has a working organization for the process of analyzing the data and translating the discovered principles for the use of engineers been adequately provided. The Advisory Board has published bulletins of information on existing research projects, on apparatus for research and the Director has written many occasional papers. Its Research Committees has summarized progress. Much remains to be done, however, in unlocking the stored up data in the files of the State highway-commissions that are now such active agencies in highway research.

The executive committee of the Board, which is a subsidiary of the engineering division of the National Research Council, is constituted of A. N. Johnson, chairman; A. F. Flinn, vice-chairman; W. K. Hatt, director; H. C. Dickinson, T. R. Agg, T. H. MacDonald, C. H. Upham, and A. J. Brosseau.

HERSCHEL BLAKE KNAP

FOLLOWING an illness of only a few days, Herschel Blake Knap, service engineer for the Packard Motor Car Co., Detroit, died on Feb. 1, 1924, in Grace Hospital in that city, aged 35 years. He was born July 1, 1888, at Bloomington, Ill., and received his preliminary education during a 4-year course at the University High School in Chicago. Then entering Cornell University, he completed the course required in Sibley College for the degree of Mechanical Engineer, and was graduated with that honor in 1911. That same year, he became a draftsman for the Packard Company and continued in its service in increasingly important capacities until his untimely death. His activities as service engineer of the Packard Company gained him the respect of service-men generally.

Mr. Knap is survived by his widow, Mrs. Eleanor Springer Knap, and by his father and mother, Dr. and Mrs. W. H. Knap, of Swarthmore, Pa. He was elected to Junior Member grade in the Society, Feb. 10, 1912, and, Sept. 8, 1915, was transferred to Member grade. Mr. Knap was a member of the Standards Committee for several years.

Applicants *for* Membership

The applications for membership received between Jan. 15 and Feb. 15, 1924, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

APPEL, GEORGE C., electrical engineer, Harley Davidson Motor Co., *Milwaukee.*

BARNES, JAMES P., president, Louisville Railway Co., *Louisville, Ky.*

BATCHELDER, FRANK B., supervising engineer, Murray Rubber Co., *Trenton, N. J.*

BEST, HERBERT W., experimental assistant, International Motor Co., *New York City.*

BLATZ, RAY W., tool engineer, Chevrolet Motor Co., *Flint, Mich.*

BROWN, CREMER F., C. G. Spring Co., *Detroit.*

BROWN, FRANCIS P., engineer in charge of grinding machine design, Brown & Sharpe Mfg. Co., *Providence, R. I.*

BROWNING, HARRISON, student, Massachusetts Institute of Technology, *Cambridge, Mass.*

BURNS, CHARLES L., assistant to works manager, Wright Aeronautical Corporation, *Paterson, N. J.*

BURROUGHS, JOSEPH H., chief engineer, Kelsey Motor Co., *Belleville, N. J.*

CHOPIN, ARTHUR EMILE, superintendent, Barry B. Cann, *Waterbury, Conn.*

COLE, O. R., supervisor of motor vehicles, Pacific Telephone & Telegraph Co., *San Francisco*

DAUGHERTY, G. A., chief draftsman, Sheldon Axle & Spring Co., *Wilkes-Barre, Pa.*

DUNLAP, JAMES P., student, Armour Institute of Technology, *Chicago.*

DUNLEVY, LORIMER, works manager, Climax Engineering Co., *Clinton, Iowa.*

DUNWOODIE, DAVID M., factory superintendent, McCook Field, *Dayton, Ohio.*

EMMONS, C. D., president, United Railways & Electric Co. of Baltimore, *Baltimore.*

FAUSER, FRED J., time study engineer, Ternstedt Mfg. Co., *Detroit.*

FORMICA INSULATION CO., *Cincinnati.*

GAMMON, THEODORE O., manager of Detroit branch, Durand Steel Locker Co., *Detroit.*

GANS, ROBERT S., president, Columbus Co., *Columbus, Ohio.*

GRAHN, RAY FREDERICK, student, Armour Institute of Technology, *Chicago.*

GUMPPER, HAROLD D., president, Gordon & Gumpper, Inc., *Detroit.*

HALLIDAY, JOHN T., draftsman, Pierce-Arrow Motor Car Co., *Buffalo.*

HALLIGAN, WILLIAM C., draftsman, Yellow Sleeve Valve Engine Works, *East Moline, Ill.*

HAYNES, H. H., aeronautical designer, Goodyear Tire & Rubber Co., *Akron, Ohio.*

JACOBS, CHARLES W., service manager, Pence Auto Co., *Minneapolis.*

JORDANOFF, ASSEN C., engineer, Chance Vought Corporation, *Long Island City, N. Y.*

KAROW, HENRY ELMER, student, Armour Institute of Technology, *Chicago.*

KINSMAN, GEORGE C., student, Armour Institute of Technology, *Chicago.*

LOTHROP, MARCUS, student, Leland Stanford, Jr., University, *Stanford University, Cal.*

LUCAS, THEODORE, consulting engineer, *New York City.*

MA, KAI YEN, student, University of Michigan, *Ann Arbor, Mich.*

MELIN, SIGURD, electrical inspector, Cleveland Automobile Co., *Cleveland.*

MILL, EDWARD O., sales manager, Anthony Motors, Inc., *Minneapolis.*

MILLER, P. O., assistant branch manager, Robert Bosch Magneto Co., Inc., *Chicago.*

MILLS, HARVEY FRETZ, research assistant, Purdue University, *Lafayette, Ind.*

MORITZ, JULIUS H., draftsman, Garford Motor Truck Co., *Lima, Ohio.*

MORITZ, WILLIAM H., draftsman, Garford Motor Truck Co., *Lima, Ohio.*

NELSON, CARL AUGUST, student, Armour Institute of Technology, *Chicago.*

NIEDERMILLER, F. J., salesman, William Ganshow Co., *Chicago.*

NICHOLSON, J. T., service manager, Cleveland Automobile Co., *Cleveland.*

NIPPS, LEROY H., student, Kansas State Agricultural College, *Manhattan, Kan.*

NOACK, EDWIN O., vice-president and general manager, Roamer Motors Corporation, *Taunton, Mass.*

NYE, NORMAN H., student, University of Akron, *Akron, Ohio.*

OWEN, H. THURSTON, consulting engineer, National Gauge Equipment Co., *New York City.*

PALMER, LOUIS HOOKER, general manager, United Railways & Electric Co. of Baltimore, *Baltimore.*

PATTON, EDWARD, general sales manager, Cleveland Used Car Bureau, *Cleveland.*

PICKENS, RUSSELL A., JR., student, Tufts College, *Medford, Mass.*

REHBERGER, EDWARD A., secretary and treasurer, Arthur Rehberger & Son, Inc., *Newark, N. J.*

RESKE, NORMAN W., detailer, Packard Motor Car Co., *Detroit.*

ROBERTS, C. EVANS, student, Stevens Institute of Technology, *Hoboken, N. J.*

ROTTMUELLER, CARL F., drafting, Ahrens-Fox Fire Engine Co., *Cincinnati.*

SATTERFIELD, GEORGE M., sales manager, Gabriel Snubber Sales & Service Co., *Detroit.*

SCHERER, JOHN OTTO, draftsman, Ford Motor Co., *Dearborn, Mich.*

SCRIBANS, JOSEPH FRANK, student, Armour Institute of Technology, *Chicago.*

SMITH, CHESTER A., manager, parts and service division, Chevrolet Motor Co., *North Tarrytown, N. Y.*

STILWELL, JOHN, general superintendent of transportation, Consolidated Gas Co. of New York, *New York City.*

TREIBER, OTIS D., charge of engineering, Bessemer Gas Engine Co., *Grove City, Pa.*

VORAS, EDWIN, student, Purdue University, *Lafayette, Ind.*

WATTS, WILLIAM SEWELL, student, Tri-State College, *Angola, Ind.*

WEBBS, ROLAND R., student, University of Michigan, *Ann Arbor, Mich.*

WEDIN, GEORGE E., engineer, International Harvester Co., *Akron, Ohio.*

WEGNER, ELMER G., student, Armour Institute of Technology, *Chicago.*

WHEELER, EDWARD WILLIAM, purchasing agent and assistant chief engineer, Linn Mfg. Corporation, *Morris, N. Y.*

WILLIFORD, E. ALLAN, assistant sales manager, National Carbon Co., Inc., *Cleveland.*

WILLSON, H. C., consulting engineer, *Detroit.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 9, 1924. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ALEXANDER, ALBERT N. (A) industrial engineer, Murray Rubber Co., *Trenton, N. J.*

ATKINSON, E. S. (A) sales manager, H. B. Sherman Mfg. Co., *Battle Creek, Mich.*

AYERS, DONALD J. (J) chief engineer, Anthony Co., Inc., *Streator, Ill.*, (mail) Y. M. C. A.

BABB, C. L. (E S) student, Purdue University, Lafayette, Ind., (mail) 131 Pierce Street, *West Lafayette, Ind.*

BAILEY, H. P. (A) manager of the business development department, Warner & Swasey Co., 5701 Carnegie Avenue, *Cleveland.*

BAKER, JAMES T. (A) instructor, School of Automotive Electricity, *Milwaukee*, (mail) 254 Oneida Street.

BANGEL, F. NORMAN (A) salesman, Van Iderstine Co., Long Island City, N. Y., (mail) 2329 Catalpa Avenue, *Brooklyn, N. Y.*

BEST, FRANCIS CLARENCE (J) chassis draftsman, Packard Motor Car Co., *Detroit*, (mail) 12732 Freud Street.

BOICOURT, J. C. (E S) student, Purdue University, Lafayette, Ind., (mail) 416 Main Street, *West Lafayette, Ind.*

BRYSON, WILLIAM R. (A) designer, Rickenbacker Motor Co., *Detroit*, (mail) 2151 Lakeview Avenue.

BURGESS, LAURENCE EDWARD (E S) student, University of Michigan, Ann Arbor, Mich., (mail) 1334 Buffalo Avenue, N. E., *Grand Rapids, Mich.*

CAMERON, ALBERT BOYERS (E S) student, Purdue University, Lafayette, Ind., (mail) 118 North Nebraska Street, *Marion, Ind.*

CHANDLER, FRED C., JR. (J) assistant to the vice-president, Chandler Motor Car Co., *Cleveland.*

CHRISTENSEN, ALFRED (J) mechanical draftsman, Rock Island Arsenal, Rock Island, Ill., (mail) 3210 Arthington Street, *Chicago.*

CORBIN, ELBERT A., JR. (M) assistant chief engineer, Philadelphia Motor Coach Co., Inc., Philadelphia, (mail) 134 Rutgers Avenue, *Swarthmore, Pa.*

COWIE, ERNEST S. (M) president, E. S. Cowie Electric Co., 1818 McGee Street, *Kansas City, Mo.*

COYNE, J. HEBER (M) automotive engineer, D. McCall White, *Detroit*, (mail) 190 East Grand Boulevard.

CROCKETT, CLARENCE VAIL, JR. (E S) student, Purdue University, Lafayette, Ind., (mail) 314 Russell Street, *West Lafayette, Ind.*

CROSSLAND, R. O. (E S) student, Purdue University, Lafayette, Ind., (mail) 105 Sylvia Street, *West Lafayette, Ind.*

DALTON, HERBERT (M) tool and die designer, engineering department, General Motors Truck Co., *Pontiac, Mich.*, (mail) 58 Fairgrove Avenue.

DUDLEY, J. KYLE (A) transmission engineer, Maxwell Motor Corporation, *Detroit*, (mail) 156 Elmhurst Avenue.

FEZANDIE, EUGENE (J) instructor, Stevens Institute of Technology, *Hoboken, N. J.*

FINCH, O. F. (M) chief draftsman, Duesenberg Automobile & Motors Co., Inc., *Indianapolis*, (mail) 2231 North Capitol Avenue.

FORS, ARTHUR R. (M) production engineer, Continental Motors Corporation, *Detroit.*

FULLER, WAYNE R. (A) technical director, Pratt & Lambert, Inc., 7397 Tonawanda Street, *Buffalo, N. Y.*

GANTES, RAMON (A) mechanical engineer, Victory V-Belt Co., *Catasauqua, Pa.*

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